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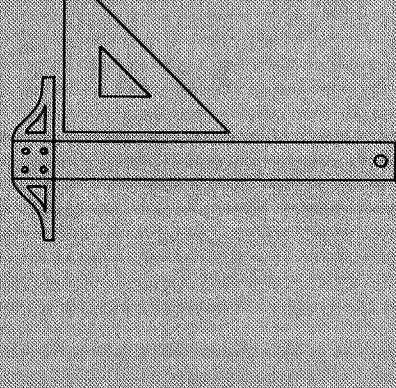
SPACE RESOURCES FOR THE HIGH SCHOOL

industrial arts resource units



national aeronautics and space administration

SPACE RESOURCES FOR THE HIGH SCHOOL

industrial arts resource units

Prepared for the National Aeronautics and Space Administration by a committee of industrial arts educators under the direction of John L. Feirer, Western Michigan University, in connection with a conference conducted by the University of South Florida, with the cooperation of the Florida State Department of Education and NASA's John F. Kennedy Space Center.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C. 20546
April, 1967

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preface

INDUSTRIAL ARTS AND SPACE TECHNOLOGY

Industrial arts has been defined as the study of tools, materials, processes, products, occupations, and related problems of America's industrial society. As such, the profession of industrial arts teaching necessarily concerns itself with those societal developments which have relevance to its area of study. America's space program is such a development. In the effort to increase mankind's knowledge of the heavens and the earth through the use of manned and unmanned spacecraft, America's space program has developed new tools, new materials, new processes, as well as new jobs, unheard of 10 years ago. It has provided great impetus to accelerating advancements and developments in science and technology, and the resulting changes in patterns for living.

Recognizing the nature, magnitude, and potential of these changes already effected and underway, a group of industrial arts educators, representative of colleges and universities, state and local school departments, and the National Aeronautics and Space Administration designed this publication. It is being made available to teachers, supervisors, curriculum makers, textbooks writers, and teachers of teachers to introduce these changes to shop and classroom teaching.

HOW THIS DOCUMENT WAS DEVELOPED

This document was prepared for the National Aeronautics and Space Administration by a representative committee of leaders in industrial arts education under the chairmanship of Dr. John L. Feirer, Western Michigan University. It was accomplished in connection with the three-day "Space Technology Conference for Industrial Arts Educators" (program on pages 170–175) conducted by the University of South Florida in cooperation with the Florida State Department of Education and the NASA John F. Kennedy Space Center.

Dr. Feirer's committee utilized the talents of 85 Conference par-

ticipants invited from the profession of industrial arts teaching in state and local school departments and institutions of higher learning of Florida, Georgia, Puerto Rico and Virgin Islands.

Following preliminary sessions of the committee, its members met with Conference participants in small group sessions, each comprising 10–15 representatives of one of the several teaching fields of industrial arts. The committee leaders and their affiliations were as follows:

Dr. Thomas Brennan, Coordinator
Industrial Education
West Virginia University
Morgantown, West Virginia

Dr. George Ditlow, Professor
Industrial Education Department
Millersville State College
Millersville, Pennsylvania

Dr. Ira H. Johnson, Professor
Industrial Arts Department
Mankato State College
Mankato, Minnesota

Dr. John R. Lindbeck, Professor
Industrial Education Department
Western Michigan University
Kalamazoo, Michigan

Mr. Warren Smith, Coordinator
Technical Sciences
Nova High School
Fort Lauderdale, Florida

In the three months following the Conference, this bulletin was prepared, compiled and edited. Since then the materials presented have been field tested in industrial arts classrooms and at teacher workshops at a number of schools and colleges throughout the country. Resources for the Committee and Conference were selected engineers, supervisors, technicians, and craftsmen from NASA and the space industries located at Cape Kennedy. Also available were selected NASA publications.

The completed report represents a document which provides the teacher with specific suggestions on ways and means that space related elements may be fused into the industrial arts courses; some of the teaching ideas are in the form of units, some in the form of activities.

Each teaching topic has a bibliography composed of specific NASA Technical Briefs, NASA Special Publications and commercially available texts representative of the very latest developments in technology.

USING THIS BULLETIN

This bulletin is addressed to industrial arts teachers, supervisors, and teacher educators. It is designed as a reference manual that can be used at all levels of instruction in all areas of industrial arts. It should be noted, however, that *it is not a course of study in space technology;* and, therefore, not all learning units found in typical industrial arts programs are represented in Section II. It was decided that only those areas in which there was a direct aerospace application should be emphasized. This bulletin is designed to motivate and interest teachers and students in aerospace age education. It is not intended to replace existing industrial arts courses. While all of the readers of this bulletin may not have an opportunty for firsthand inspection of the John F. Kennedy Space Center, the directors and teachers who

were in attendance at the conference feel that, if some of the ideas presented here are integrated into industrial arts, interest and enthusiasm for industrial arts will increase greatly. The individual teacher can use as few or as many of the suggestions as he feels necessary to enrich his present program. The following are some suggested ways to make efficient use of this bulletin:

1. *As a self-improvement program.* Review the materials that are available from NASA (National Aeronautics and Space Administration) including the services listed on pages 158 to 160. The teacher will note that there is a wide variety of technical literature and audio-visual materials available. These materials can form the basis for developing a shop or laboratory library on space age activities, and in this process a teacher cannot fail to acquire a new appreciation for the value of industrial arts in space technology. The teacher may also arrange to have the Spacemobile and a NASA lecturer come to his school so all students can hear about and see some of the achievements of the space program. He may also use any one of the excellent films that are available to introduce the subject. A good motivating device for introducing this material to industrial arts students is the film "The Big Challenge." This film is available on loan from the center serving your state (see pages 161 to 169). Once the students have been motivated, the teacher can use much of the material in Section 2 as part of his regular teaching procedure. The material on aerospace age applications can be used in individual lessons including demonstrations and lectures. Many of the ideas included are suggestions from classroom teachers who participated in the conference. The teacher may also develop a teaching unit similar to some of the samples included in Section 2. Section 3 includes many suggestions for teachers who are interested in the new frontiers of industrial arts.

2. *As a school improvement.* The industrial arts teacher can work with the science, mathematics, and guidance counselors to improve all of the programs. For example, this bulletin can be used along with the *Occupational Outlook Handbook* and the *Dictionary of Occupational Titles* to interest students in occupations directly and indirectly related to the aerospace industry. The school counselor could serve as the resource person for this part of the program. Many of the ideas included in Section 3 would lend themselves to development through the team teaching approach, particularly with teachers in science and mathematics.

3. *For professional improvement.* A great deal of action is needed by industrial arts educators throughout the United States to implement space technology in industrial arts. The effectiveness of this bulletin will depend almost fully on how many industrial arts teachers make use of the suggestions and ideas included herein. There are many things that the industrial arts profession can do as

a group to interest its professional personnel in aerospace education. The following is a list of some worthwhile activities. Each individual may add his own to the list.

a. Conduct in-service workshops for industrial arts teachers using space technology as the theme. Clubs and groups of industrial arts teachers throughout the United States who meet regularly in small groups would do well to devote one or several of their meetings to aerospace education. Whenever possible, they should make use of individuals in their local area as resource persons. In almost every part of the United States there are contractors and subcontractors who are involved in the space program.

b. Arrange to have state and national conventions devote a day to programs on aerospace education utilizing speakers and displays from NASA.

c. Have NDEA institutes for industrial arts use this bulletin as a basis for a short or long-term program of improvement.

d. Add aerospace projects as one of the categories for local and state project contests. Too many of the existing project contests emphasize only the traditional areas.

e. Development of master's and doctoral theses centered around an in-depth study of some aspect of space technology.

f. Institute research studies that relate space technology to industrial arts. These studies may be funded under one of the several Federal programs that give support for research and new innovation programs.

g. Interest industries who are contractors or subcontractors to make available samples, specimens, drawings, prints, and other materials that can be used in teaching. Many manufacturers who work for NASA often have rejects or obsolete material that would be extremely valuable to industrial arts teachers. A national clearing house is needed so that teachers will know what materials are available and how they can be obtained.

h. Prepare audio-visual materials, particularly films, overhead projector material, charts, and other tools that are designed specifically to relate space age technology to industrial arts.

Space is the new frontier of science and technology; and if industrial arts is to give students an insight into American industries, teachers must be more concerned with space age technology. The image of industrial arts will be greatly improved in the eyes of students, parents, administrators, and the lay public when teachers utilize some of the materials included in this bulletin.

The teacher using this bulletin should also note that there are several sample teaching units in Section 2. These are organized in a wide variety of styles and teaching patterns. A teacher can select the organization that best suits his particular teaching situation.

The teacher should also note the simplified code used to identify reference materials. This code is as follows:

Subject Area Code	**Instructional Material Code**
1. Design and drafting	A. Textbooks
2. Metals	B. NASA Bound Documents
3. Electricity	C. NASA Tech Briefs
4. Power	D. NASA Fact Sheets and NASA FACTS
5. Graphic Arts	E. NASA Films
6. Plastics	F. Miscellaneous
7. Ceramics	
8. Woods	

For example, if the reference indicates that it is 2B1, it means that it is a reference in metalworking from the NASA bound documents and is the first on the list at the end of that unit.

section 1

UNIT I—THE AEROSPACE INDUSTRY

AN OVERVIEW

The details of space flight and the numerous scientific space probes have become as much a part of the vocabulary of the youngster today as were the automobile and airplane not too many years ago. This has come about because of a constant public exposure to the facts and illustrations of the space age. However often the space flights are seen on television or in the newspapers, it is difficult to grasp the magnitude of the total effort required for a successful launch.

The National Aeronautics and Space Administration, since its establishment in 1958, has harnessed the infinitely diverse skills of the nation for the most meaningful technological goal ever established: space exploration.

Congress defined NASA's mission in October 1958: Manage the scientific exploration of space, send men there to reconnoiter, use space technology to promote human welfare. This responsibility was given to NASA in addition to its assignment in the field of aeronautical research and development. Basically, the aerospace industry provides the equipment and the techniques specified by NASA to take men and his machines beyond earth and return—safely.

It is hard to realize that the space mission begins many years before the dramatic climax of a tremendous vehicle blasting off into space. This is the most dramatic episode in the space mission; however, it is but one brief episode in the total picture. It is, in fact, the culmination of years of work involving hundreds of thousands of hours of human effort and millions of dollars worth of equipment. Although the Kennedy Space Center is most often in the news because it is from this site that some of our most successful and dramatic shots have been made, it is just one of many NASA locations. The map, on page 14, graphically illustrates the complexity of this total effort by indicating the many NASA installations we find in this country. At each of these facilities the development and perfection of many sophisticated systems which go into each space vehicle take place. The map only shows the NASA research and development facilities found in this country. There are many tracking and telemetry stations all over the world which feed back to us electronically, information and progress reports of space flights.

But this is still not the complete story. Twenty thousand factories and laboratories employing almost 400,000 men and women were involved in the nation's space program for peaceful purposes during

section 1

1966—contractors and subcontractors for components of the space vehicles; for providing test, maintenance, security and housekeeping facilities; and for providing technical assistance in communications and telemetry. See Fig. 1–1.

In the Apollo program which is designed to carry man to the moon, more than 300,000 persons are involved in making the hardware for this great adventure down to tiny bolts for the spacecraft and almost invisible microcircuits for the computers. Many other government agencies are also involved in the total space effort, each with a primary space mission or as a support facility.

Nor is the United States alone in its space efforts. The previously mentioned tracking and telemetry facilities found throughout the world are indicative of the kind of international cooperation required in the success of any space venture. The steadily expanding program

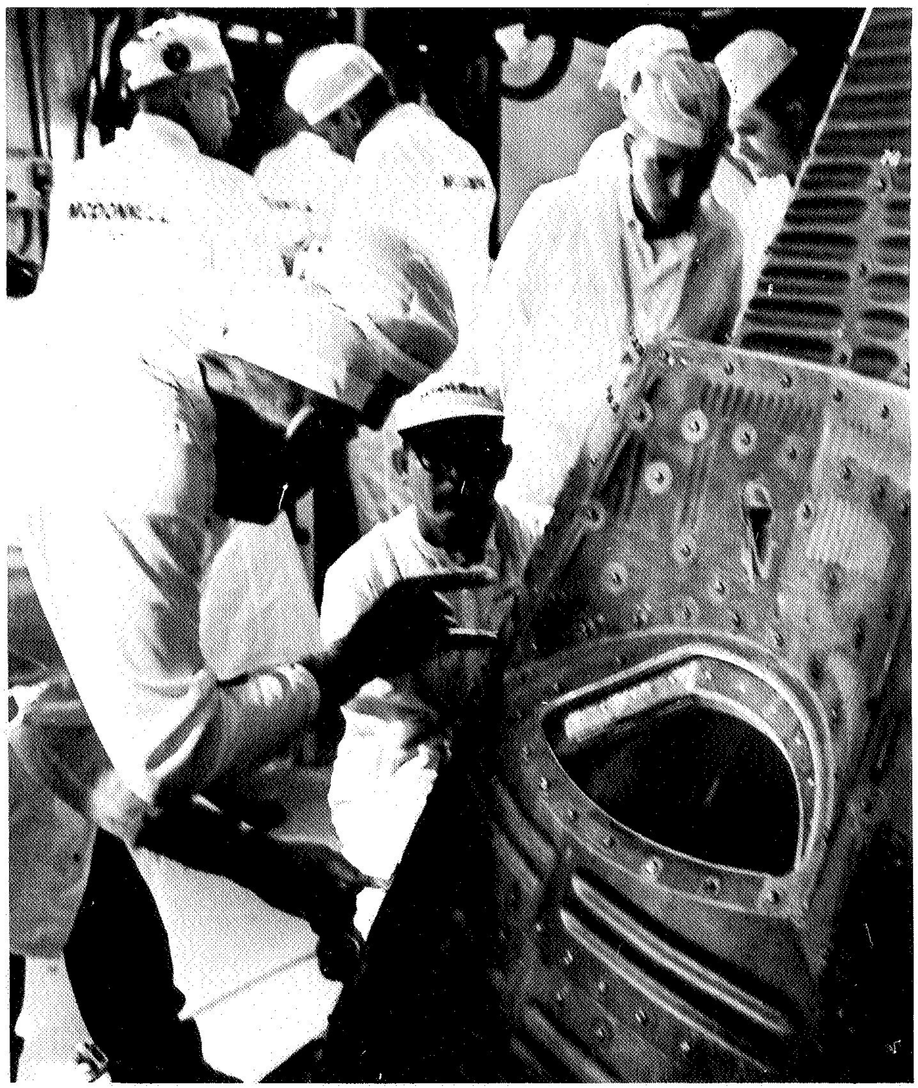


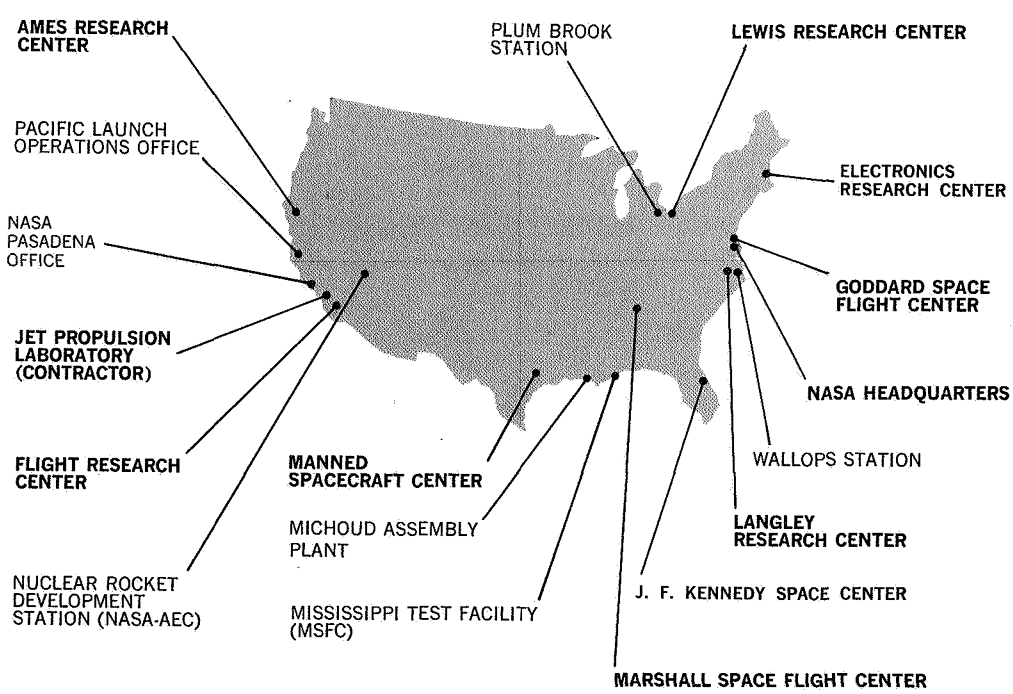
Fig. 1–1. Technicians of McDonnell Company seal the spacecraft hatches on astronauts Frank Borman, Command Pilot, and James Lovell, Jr., Pilot, 75 minutes prior to a launch from the National Aeronautics and Space Administration's John F. Kennedy Space Center.

of international cooperation in the exploration of space is illustrated by the joint United Kingdom-United States satellite called Ariel II which was launched in March of 1964. Ariel's primary mission was to contribute to man's knowledge of the ionosphere. A satellite with a similar mission—the Allouette II—was a joint Canadian-American venture launched in 1965. Other joint programs ranging from operational support and ground based projects to experiments on board NASA satellites and satellites themselves are now in operation with over 60 countries. The breadth and the complexity of the aerospace industry is staggering to the imagination.

A particularly significant aspect of the space program is that, in its breadth, it involves almost every known science and technology—physics, chemistry, biology, astronomy, geology, geodesy and cartography, heat studies, cryogenics, particles and fields, to name but a few—and its needs spread across the entire industrial spectrum—electronics, metals, fuels, ceramics, machinery, plastics, instruments, textiles and others. Most importantly it involves manpower. Not the production-line oriented worker doing simple repetitive tasks, but rather the individual craftsman and artisan. The demand for quality with no leeway for defect has brought back the pride of workmanship and skill level requirements of days gone by.

A new frontier faces us. The pioneer in this frontier will be man—man qualified by training and education.

NASA INSTALLATIONS



NASA FACILITIES AND MISSIONS

NASA Headquarters, Washington, D.C.
Formulates policy and coordinates the activities of the space flight centers, research centers, and other installations in NASA.

Ames Research Center, Moffett Field, California
Laboratory and flight research in unmanned space flight projects and in aeronautics.

Electronics Research Center, Cambridge, Massachusetts
Stimulate research and advanced development in electronics and related fields for application in space and aeronautics.

Flight Research Center, Edwards, California
Concerned with manned flight within and outside the atmosphere, including low speed, supersonic, hypersonic, re-entry flight, air operation, and safety problems.

Goddard Space Flight Center, Greenbelt, Maryland
Responsible for the development and management of a broad variety of unmanned earth orbiting satellites and sounding rocket projects. Included are scientific, communication, and meteorological satellites.

Jet Propulsion Laboratory, Pasadena, California
Under contract to NASA by California Institute of Technology. Its missions are the development of spacecraft for unmanned lunar and planetary exploration and the operation of a world-wide deep space tracking and control network.

John F. Kennedy Space Center, Florida
Manned and unmanned spacecraft are launched here. Functions include planning, designing, development, and utilization of launching facilities.

Langley Research Center, Hampton, Virginia
Task of providing technology for manned and unmanned exploration of space and for improvement and extension of performance and utility of aircraft. Major technical areas are theoretical and experimental dynamics of flight through the entire speed range, flight mechanics, materials and structure, space mechanics, instrumentation, solid rocket technology, and advanced engine research.

Lewis Research Center, Cleveland, Ohio
Mission is propulsion and space power generation. Fields of investigation are materials and metallurgy, problems concerned with the use of extremely high and low temperature materials, combustion and direct energy conversion, chemical, nuclear, and rocket propulsion systems to name some.

Plum Brook Station, Sandusky, Ohio
An arm of Lewis Research Center with facilities for nuclear propulsion research and development.

Manned Spacecraft Center, Houston, Texas
Responsibility for the design, development, and testing of manned spacecraft and associated systems for the selection and training of astronauts and for operation of manned space flights.

George C. Marshall Space Flight Center, Huntsville, Alabama
Launch vehicles are designed and developed. Concerned with studying rendezvous operations, launch systems, feasibility, and other requirements.

Michoud Operations, Michoud, Louisiana
Manufacture Saturn and other large launch vehicles.

Nuclear Rocket Development Station, Jackass Flats, Nevada
Joint operation of NASA and Atomic Energy Commission containing laboratories, test stands, and equipment for the development of reactor technology and the nuclear engine and rocket stage for the nuclear rocket.

Pacific Launch Operations Office, Lompoc, California
NASA Pacific launch operations office provides administrative, logistic, and technical support for NASA programs at the western test range.

Wallops Station, Wallops Island, Virginia
The rocket borne experiments are flown from here. Function is payload checkout, vehicle preparation and launching, instrumentation and data acquisition, processing and reduction of data, and tracking of vehicles.

NASA Pasadena Office, Pasadena, California
Operations office serving all operational interests of the agency in the Western States. Primary mission is contract negotiation and management of research and development contracts with western aerospace industry.

section 1

UNIT 2—PRODUCTS AND MATERIALS

You have often heard that the United States is a great industrial nation, a nation which in part owes its high living standard and its position in the world to an ability to mass produce high quality products. When you think of the term "industry," you probably think of certain industries, such as the automobile industry, the aerospace industry, or, perhaps, the plastics industry. The point is that there are many kinds of industries each playing their part in producing the things necessary for comfortable living. Let's take a closer look at industries to see what they are and how they work.

THE ESSENTIALS OF INDUSTRY

An industry is the sum total of all of the activities required to produce a commodity. By commodity we mean such things as television and theater entertainment or the facilities for repairing your automobile as well as products such as boats, furniture, tools, airplanes, or space rockets. You can see that industry is involved with the production of services *and* goods. Industries, however, don't just happen. It takes initiative and effort by free individuals to get ideas and work to see these ideas come into being.

Every industry is made up of three basic essentials: Natural Resources, Capital Resources, and Human Resources. *Natural Resources* provide the raw material which must be changed or worked in order to be used. *Capital Resources* include the money, the factory, the machines, the power, and the transportation-communication facilities used in transforming the natural resources. *Human Resources* include the inventors, the planners, and the supervisors who direct the production activities as well as the work force of skilled individuals to operate machines and assemble and test the things we use. These are the *essentials* of industry. Whether the commodity is a product or a service, these must operate together in order for the industry to provide that commodity.

THE ELEMENTS OF INDUSTRY

Industrial arts is primarily concerned with those industries which

produce goods. In other words, it concentrates on the manufacturing industries and is concerned with the ways in which raw materials are transformed into usable products. One should realize and appreciate the fact that the products we take for granted are the result of much planning and effort by many people. How does the product get from the "idea" stage to the consumer or the person who uses it? The chart in Fig. 2–1 shows the elements of industry, a graphic record of how products are planned, made, and sold in great quantities.

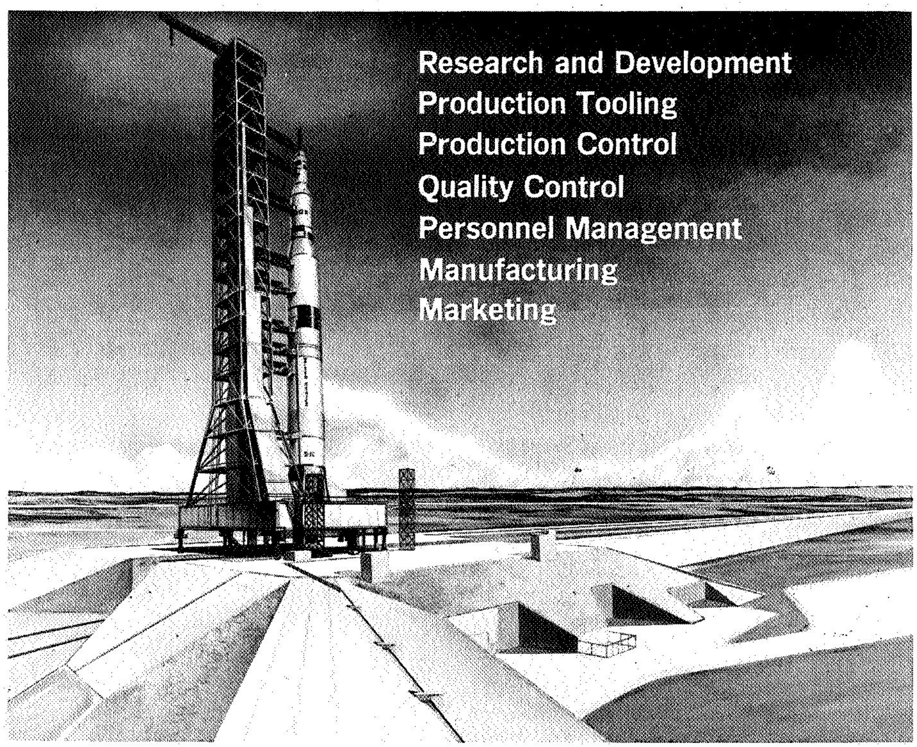


Fig. 2–1.

The planners and designers of products are the people responsible for *research* and *development.* This is where design ideas originate. These designs are given to *production tooling* and *control* staffs who plan special tools and the methods of moving materials on the production line. *Quality control* experts plan methods of checking the standards of the product to make certain they are well made. The *personnel management* specialists select and train the people to work as machine operators and assemblers on the production line. After all the necessary planning has been done, there remains only the *manufacturing* and *marketing* of the product.

The prime function of a complex and sophisticated industrial organization is to *mass produce* high quality products. In the aerospace industry, however, it is interesting to note the major effort is towards the handcrafting of one, two, or three units of a product rather than producing it in quantity. When we think of aerospace production, our whole outlook changes. We must reorient ourselves to a scheme of producing relatively few models of a product but of optimum quality. The concept of zero error enters the picture; the lives of the astronauts

and the success of a multimillion dollar space venture depends upon the skill and dedication of the workers who plan and put together the space vehicle.

The elements of industry are the same whether you are producing bicycles or rockets; only the matters of numbers of products and, perhaps, more rigid specifications are different. Even those aspects of marketing which deal with transportation and servicing are found in aerospace production.

RELATIONSHIP TO INDUSTRIAL ARTS

By this time you have become aware of the magnitude of the aerospace industry; an industry encompassing many people working in many kinds of jobs. This space age industry can be said to be made up of a number of other industrial organizations, as shown in Fig. 2–2. Space vehicles require products made of ceramics, plastic, and metal as well as the power and electronic components. It is evident that industrial arts can make a significant contribution to understanding the aerospace industry because it, too, is concerned with the same areas, as are shown in Fig. 2–2. Industrial arts students work with the principles and the skills necessary to produce, propel, and control spacecraft. Fig. 2–3 shows graphically the kinds of systems present in these crafts and gives further evidence of the many opportunities for industrial arts teachers to help acquaint their students with the products and processes of the space age.

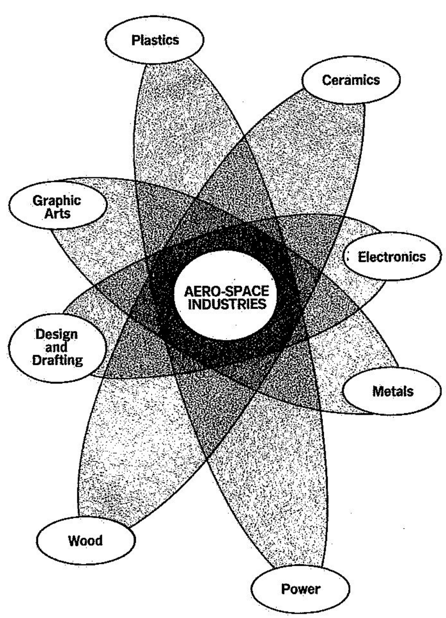


Fig. 2–2.

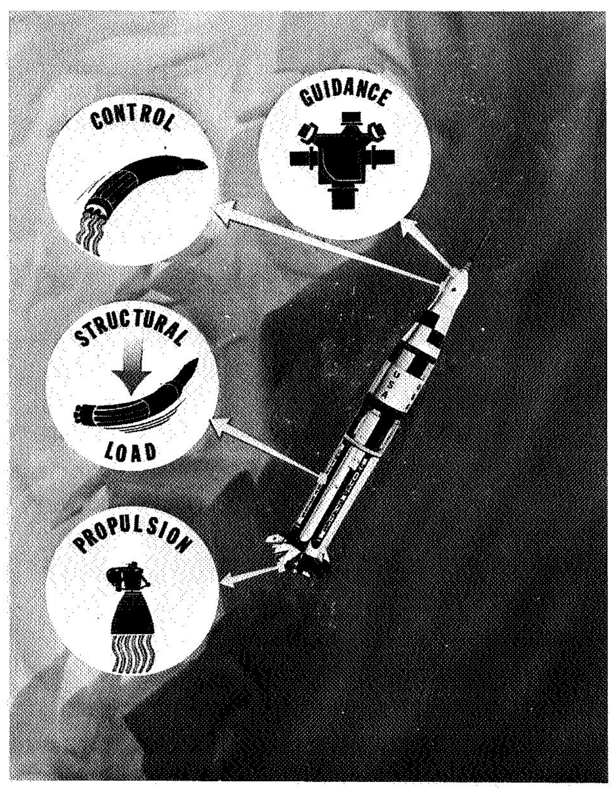


Fig. 2–3.

section 1

UNIT 3—AEROSPACE OCCUPATIONS

Because of the tremendous scope of the activities of NASA and the entire aerospace program, the career implications for this industry are indeed broad. There are at present over 1.3 million people employed in aerospace manufacturing. Of these, ½ million are at work producing missiles and spacecraft, and 150,000 work in the electronics field. These figures give some idea of the number of people needed to work as engineers, scientists, technicians, and skilled mechanics and craftsmen. What kinds of skills are needed? Let's look at one area—drafting—to see how it relates to the aerospace program and what kinds of drafting jobs are performed.

One drafting job relates to ground support facilities which house the electrical equipment used in all phases of launch vehicle checkout. An engineer might work out the electrical design for a circuit, and a draftsman would make a drawing of the system for the engineer. Another draftsman assists engineers in preparing, revising, and correcting blueprints of facilities dealing with electrical work and instrumentation. Such draftsmen help engineers to put their views and ideas into a graphic form so that contractors in the field will know how to construct facilities. Engineering designers prepare circuitry schematics and block diagrams for launch vehicles which are primarily applications of electronic and electrical drawing. It is interesting to note that these engineering drafting jobs are held by persons who may not have college degrees in engineering but, instead, have strong backgrounds in industrial arts drafting at the high school level. This was followed up by one or two years of technical drafting at a junior college or in an on-the-job training program with industry.

Numerous other professional engineering positions in the aerospace industry require a strong background in engineering drawing in order to accurately interpret the many engineering blueprints which cross one's desk each day. It becomes immediately evident that the opportunities for draftsmen in the space age are numerous and that an introduction to drafting in the industrial arts program in your high school can help to prepare students to enter an interesting and profitable profession as an aerospace draftsman.

Drafting is but one of the hundreds of occupations open to qualified persons who wish to work in the aerospace industry. This work includes jobs at many levels from skilled operators to technical writers to scientists and engineers.*

**Seven Steps to a Career in Space. NASA Educational Publication EP-33.*

This work includes basic and applied research for the expansion of human knowledge of phenomena in space; the improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles; and the development and operation of vehicles capable of carrying instruments, equipment, and people through space. The men and women engaged in space exploration and research have the most challenging and interesting assignment ever given to the American scientists, engineers, and technicians.

What are some of the many kinds of jobs open to qualified persons to which industrial arts can contribute? Certainly, some of the basic courses in industrial arts can introduce the students to many interesting careers in engineering. Some of these engineering specialities are aeronautical, ceramic, chemical, civil, electronic, electrical, industrial, mechanical, metallurgical, and nuclear. Technicians or engineering aides in the aforementioned engineering specialties are also needed in great numbers to support the important work of the engineering and research staffs. The skilled workers—persons who are highly trained in a speciality, and who are capable of work of high quality—are also needed in the many NASA installations throughout the United States as well as in the numerous support industries which supply components and services to the Space Administration. One does not need a college education to work in the space industry. One must, however, have a dedication to the vital nature of his job; a welder must understand that the success of an Apollo launch depends as much upon his skill in producing a welding job containing zero errors as it depends upon the research physicist and the designer in arriving at a vehicle design which is without error. Skill and reliability are perhaps the two most vital aspects of the individual's training and background. As students learn more about the space industry in industrial arts courses through films, visits, class discussions, and reading, they will come to realize that this is a team effort and that the success of the mission is dependent entirely upon individuals and a dedication to skillful and reliable performance.

Shown in the following chart are the typical industrial arts course areas and some related space occupations. Note that these occupations are followed by their *Dictionary of Occupational Titles* (DOT) numbers. The DOT may be consulted for further information regarding descriptions of these jobs.* Several examples of the DOT descriptions are included for each industrial arts area. In order to aid in your interpretation of these charts, the identification of the first digits of the code numbers are shown below.

$\left\{\begin{matrix}0\\1\end{matrix}\right.$ Professional, technical, and managerial occupations
2 Clerical and sales occupations
3 Service occupations
4 Farming, fishery, forestry, and related occupations
5 Processing occupations
6 Machine trades occupations
7 Bench work occupations
8 Structural work occupations
9 Miscellaneous occupations

**Industrial arts teachers will find the three publications listed on the following page especially helpful in occupational guidance.*

The following publications are listed below for your convenience:

U.S. Department of Labor. Dictionary of Occupational Titles, Volume I (Third Edition). U.S. Government Printing Office, 1965, Washington, D.C. $5.00

U.S. Department of Labor. Dictionary of Occupational Titles, Volume II, (Third Edition). U.S. Government Printing Office, 1965, Washington, D.C. $4.25

U.S. Department of Labor. Occupational Outlook Handbook. U.S. Government Printing Office, 1966, Washington, D.C. $5.00

INDUSTRIAL ARTS AREA

Drafting and Design
Fig. 3–1

TYPICAL AEROSPACE OCCUPATIONS

Drafting Clerk 249.281; aeronautical draftsman 002.081; architectural draftsman 001.281; design draftsman 017.168; civil draftsman 005.281; commercial draftsman 017.281; electrical draftsman 003.281; geological draftsman 010.281; heating and ventilating draftsman 017.281; map draftsman 017.281; mechanical draftsman 007.281; plumbing draftsman 017.281; refrigeration draftsman 017.281; structural draftsman 005.281; topographical draftsman 017.281; designer and template maker 781.381; design draftsman, electromechanisms 017.281; detailer 017.281; engineering assistant 007.181; aircraft engineering checker 002.281; engineering designer 002.281; aircraft designer 002.281; aeronautical (aerospace) engineer 002.081; mechanical engineer 007.081.

AERONAUTICAL ENGINEER (profess. & kin.) 002.281. Performs a variety of engineering work in design, construction, and testing of aircraft and missiles: Designs airplanes and seaplanes for military or transportation purposes, including design of propellers, sea wings, and other parts of aircraft. Designs missiles for military or scientific missions. Tests models, prototypes, subassemblies or production aircraft and missiles to study and evaluate operational characteristics and effects of stresses imposed during actual or simulated flight conditions. Oversees fabrication and assembly of prototype and production aircraft and missiles. Oversees technical phases of air transportation.

DRAFTSMAN, AERONAUTICAL (profess. & kin.) 002.281. Performs duties of DRAFTSMAN I, specializing in drafting engineering drawings of developmental or production airplanes and missiles and ancillary equipment, including launch mechanisms and scale models of prototype aircraft, as planned by AERONAUTICAL ENGINEER.

DRAFTING CLERK (clerical) 249.281. Chart man; charting draftsman. Draws and letters charts, schedules, and graphs illustrating specified data, such as wage trends, absenteeism, labor turnover, and employment needs, using drafting instruments, such as ruling and lettering pens, T-squares, and straightedge. Gathers, reviews, and arranges in sequence for graphic presentation. May use mimeoscope to prepare copies for duplication. May do paste-up work.

Fig. 3–1. Space technology problems are studied by design engineers. (above)

Fig. 3–2. Precision machining operations are very necessary to successful space ventures. (at right)

INDUSTRIAL ARTS AREA

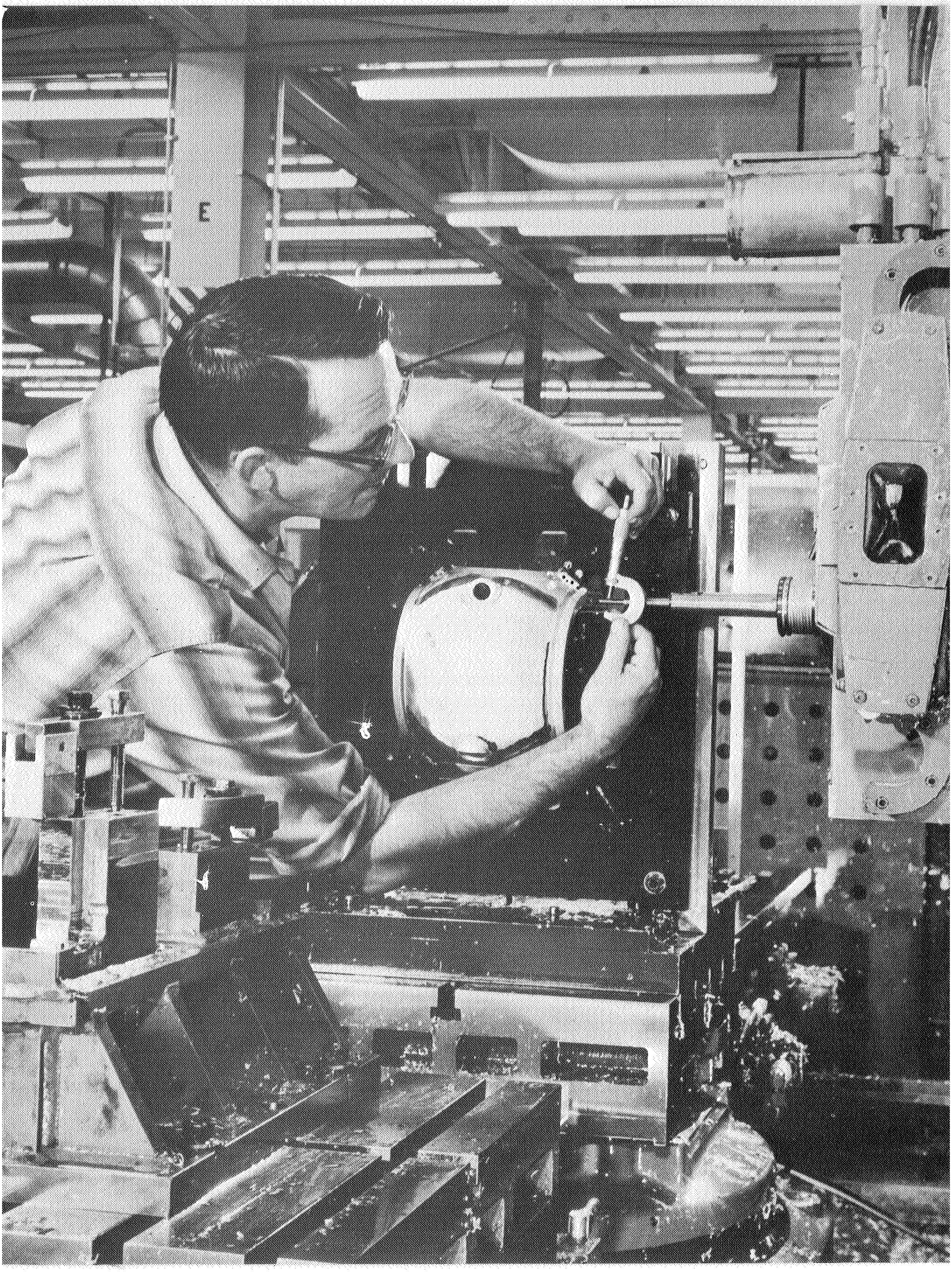
TYPICAL AEROSPACE OCCUPATIONS

DRAFTSMAN (profess. & kin.) I. Prepares clear, complete, and accurate working plans and detail drawings from rough or detailed sketches or notes for engineering or manufacturing purposes, according to specified dimensions: Makes final sketch of proposed drawing, checking dimension of parts, materials to be used, relation of one part to another, and relation of various parts to whole structure. Makes any adjustments or changes necessary or desired. Inks in all lines and letters on pencil drawings as required. Exercises manual skill in manipulation of triangle, T-square, and other drafting tools. Lays tracing paper on drawing and traces drawing in ink. Draws charts for representation of statistical data. Draws finished designs from sketches. Utilizes knowledge of various machines, engineering practices, mathematics, building materials, and other physical sciences to complete drawings. Classifications are made according to type of drafting as DRAFTSMAN, ARCHITECTURAL; DRAFTSMAN, ELECTRICAL.

Metals
Fig. 3–2

Sheet Metal: power brake operator 617.380; power shear operator 615.782; power hammer operator 617.782; punch press operator 615.782; profile cutting machine operator 816.782; sheet metal worker 804.281.

Machining and Fabricating: machinists 600.280; machine tool operator 609.885; jig and fixture builders 761.381; tool and die makers 601.280; tube benders 709.884; riveters 800.884; welders 810.782, 810.884, 811.782, 811.884, 812.884, 813.380, and 813.885; heat treater 504.782;


E

TYPICAL AEROSPACE OCCUPATIONS

painter 845.781; plater 500.380.
Assembly and Installation: final assemblers 806.781; missile assembly mechanics 652.281; armament assembler 801.381.
Inspecting and Testing: production inspector 806.381; receiving inspector 806.384; machined parts inspector 609.381; fabrication inspector 807.381; assembly inspectors 806.381.
Foundry: patternmaker 693.281; hand molder 518.381; sand mixer 579.782; core oven tender 518.885; core assembler 518.807; coresetter 518.884; melter 512.782; pourer 514.884; shakeout man 519.887; shot blaster 503.887; tumbler operator 599.885; chipper 809.884; grinder 809.884; heat treater 504.782; casting inspector 514.687.

Engineering: mechanical engineering technician 007.081; mechanical laboratory technician 609.280; mechanical test technician 869.281; mechanical engineer 007.081.

MACHINE OPERATOR (any ind.) II. 619.885. Tends fabricating machines, such as cutoff saws, shears, brakes, ironworker, straightening press, and punch, to cut, shape, bend metal plates, sheets, and structural shapes: Sets stops or guides to specified length as indicated by scale, rule, or template. Positions workpiece manually or by using hoist, against stops or alines layout marks with die or blade. Pushes button or depresses treadle to activate machine. Measures work, using rule or template. Removes burrs, sharp edges, rust, or scale using file, hand grinder, or wire brush. Performs other shop tasks, as oiling machines, dies, or workpieces, assisting machine operators to set up machine, and stacking, marking, packing, and transporting finished pieces. May also tend other machines, such as drill press, spot welder or riveting machines.

MECHANICAL-ENGINEERING TECHNICIAN (profess. & kin.) 007.181. Engineering technician; experimental technician; laboratory-development technician; mechanical technician. Applies theory and principles of mechanical engineering to develop and test machinery and equipment under direction of engineering staff and physical scientists: Reviews project instructions and blueprints to determine test specifications, procedures, objectives, test equipment, and problems involved and possible solutions, such as redesigning parts, changing material or parts, or rearranging parts or subassemblies. Prepares detailed drawings or sketches to scale for drafting room or when requesting fabrication by machine, wood, or sheet-metal shops. Develops, fabricates, and assemblies new or modified mechanical components or assemblies for machinery and equipment, such as industrial equipment and machinery, power equipment servosystems, machine tools, and measuring instruments. Sets up and conducts tests and experiments of complete units and components to investigate engineering theories regarding improvement in

design or performance of equipment, to subject equipment to simulated operating conditions, and for such purposes as development, standardization, and quality control. Analyzes indicated and calculated test results against design or rated specifications and objectives of tests and modifies equipment to meet specifications. Records test procedures, results, and suggestions for improvement. Prepares engineering drawings, charts and graphs.

Electricity-Electronics
Fig. 3-3

Electrical assembler 728.884, 720.884, 729,884, 726.781, and 726.884; grid-lathe operator 925.884; coil winder 724.781; tinner 501.885; anodizer 501.782; electronic assembly inspector 722.281; module assembler 726.884; parts changer 729.381; controls engineer 002.081; engineering analyst 020.088; instrument man 710.281; instrument maker 600.280; instrumentation technician 003.281; telephone engineer; automatic equipment technician 822.281; television repairman 720.281; television installation man 823.781; auxiliary equipment operator 952.782; lineman 821.381; radio electrician 823.281; electronic engineer 003.081; electronics assembler (developmental) 726.281.

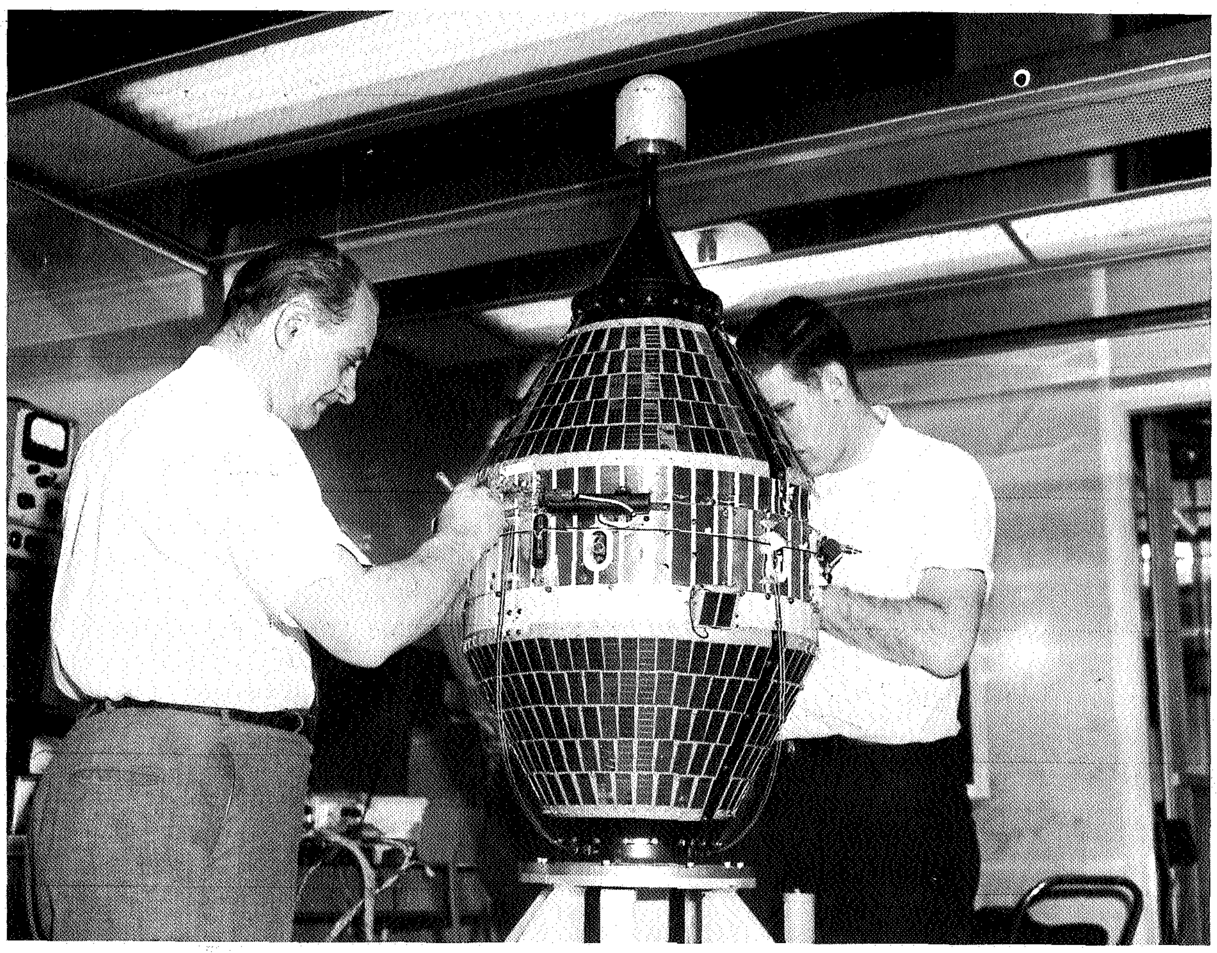


Fig. 3-3. Electronic technicians at work checking out a communications satellite.

TYPICAL AEROSPACE OCCUPATIONS

ELECTRONICS ASSEMBLER, DEVELOPMENTAL (electronics) 726.281. Assembler and wireman, special equipment; electrical mechanic; electronic assembler, prototype; electronic rework assembler; equipment wireman and assembler, special; wireman. Assembles or modifies prototypes or final experimental assemblies of electronic equipment, such as missile control systems, radio and test equipment, computers, and machine-tool numerical controls, using handtools and electronic test equipment, and following schematic or assembly drawings, sketches, and wiring diagrams: Installs components such as switches, coils, transformers, relays, transistors, and potentiometers, in assemblies, using handtools, power drills, and soldering iron. Routes and solders wire to components in assembly to form circuitry. Solders cable wires to specified terminals to connect circuits and subassemblies. Installs cables and wire harnesses to connect assemblies with power source, switch panels, and junction boxes. Assembles and laces cables [CABLE-MAKER (elec. equip.; electronics)]. Tests continuity of circuits using circuit analyzer. May assemble breadboard (experimental) layouts of electronic circuits to prove engineering design. May instruct workers in techniques of wiring and soldering. May be designated according to type of equipment assembled as RADIO-EQUIPMENT ASSEMBLER, SPECIAL.

ELECTRONIC ENGINEER (profess. & kin.) 003.081. Conducts research and development concerned with design and manufacture of vacuum and gaseous tubes, semiconductor and other solid-state devices, and electronic equipment, and their application to commercial, industrial, military, scientific and medical equipment, processes, and problems: Designs electrical circuits to specifications, utilizing ferroelectric, nonlinear, dielectric, phosphor, photoconductive, and thermoelectric properties of materials [DESIGN ENGINEER I]. Designs test apparatus and devises procedures to evaluate electronic equipment. Develops improved utilization of electric and dielectric properties of metallic and nonmetallic materials used in electronic components. May specialize in applications of electronic technology, such as telecommunications, telemetering, aerospace guidance systems, missile propulsion control, counter measures, acoustics, and nucleonic instrumentation, electronic data reduction and processing equipment, industrial controls and measurements, high-frequency heating, laboratory techniques, teaching aids, radiation detection, encephalography, electron optics, and biomedical research. May direct field operation and maintenance of electronic equipment and recommend design changes according to operational evaluation to correct errors or to accommodate changes in system requirements. May be designated according to specialization as ENGINEER, INSTRUMENTATION; SYSTEMS ENGINEER; THERMIONICS ENGINEER.

INDUSTRIAL ARTS AREA	TYPICAL AEROSPACE OCCUPATIONS
Power Fig. 3–4	Power plant installer 621.381; experimental mechanic 621.281; experimental rocket sled mechanic 825.281; experimental mechanic (research) 693.281; rocket-engine test engineer 003.081; instrument mechanic 710.281; field and service mechanic 621.281; industrial truck mechanic 620.281; automobile mechanic 620.281; engine repairman 625.281; diesel mechanic 625.281.

ROCKET-ENGINE-TEST ENGINEER (aircraft mfg.) 003.081. Specializes in environmental and ballistics testing of solid propellant rocket engines and recording of engine performance data: Designs and directs fabrication of electromechanical control apparatus. Directs development, procurement, and installation of electronic data reduction, telemetering, and recording instrumentation. Determines entire sequence of test operations and directs conditioning and firing phases of test program. Cooperates with professional and technical personnel to resolve problems concerned with incomplete test data and interpretation of test data in relation to instrumentation or methods used to derive and record it.

EXPERIMENTAL MECHANIC (aircraft mfg.) I. 693.281. Research mechanic. Fabricates experimental airplane parts for testing: Constructs plywood models [MODEL MAKER I], following experimental design, of parts, such as wing sections, armament, and heating, ventilating, fuel, and control systems. Makes form blocks, using woodworking tools, to be used in shaping metal assemblies [FORM BUILDER (aircraft mfg.; auto. mfg.)]. Cuts, shapes, and joins together experimental assemblies [SHEET-METAL WORKER (any ind.); WELDER, COMBINATION (welding)]. Machines fittings and parts [MACHINIST I (mach. shop)]. Determines and measures defects in the structures, using engineering devices that simulate flying conditions.

ROCKET-ENGINE MECHANIC (aircraft mfg.). Sets up and operates machines, such as milling machines, lathes, drill presses, and powersaws, to machine parts for experimental liquid or solid fuel rocket engines and assembles parts into completed units, following specifications: Measures parts for conformance to specifications, using calipers and micrometers. Assembles parts into completed units, such as valves, injector heads, and pressure vessels, using handtools. Operates vacuum pressure testing equipment to test assembled units for air leaks. May be designated according to specialization as ROCKET-ENGINE MECHANIC, LIQUID: ROCKET-ENGINE MECHANIC, SOLID.

Graphic Arts Fig. 3–5	Silk screen operator (electronic) 726.887; etching equipment operator (electronic) 590.885; hand compositor 973.381; linotype machine operator 650.582; monotype keyboard operator 650.582; monotype caster operator 654.782; phototypesetting machine operator 650.582;

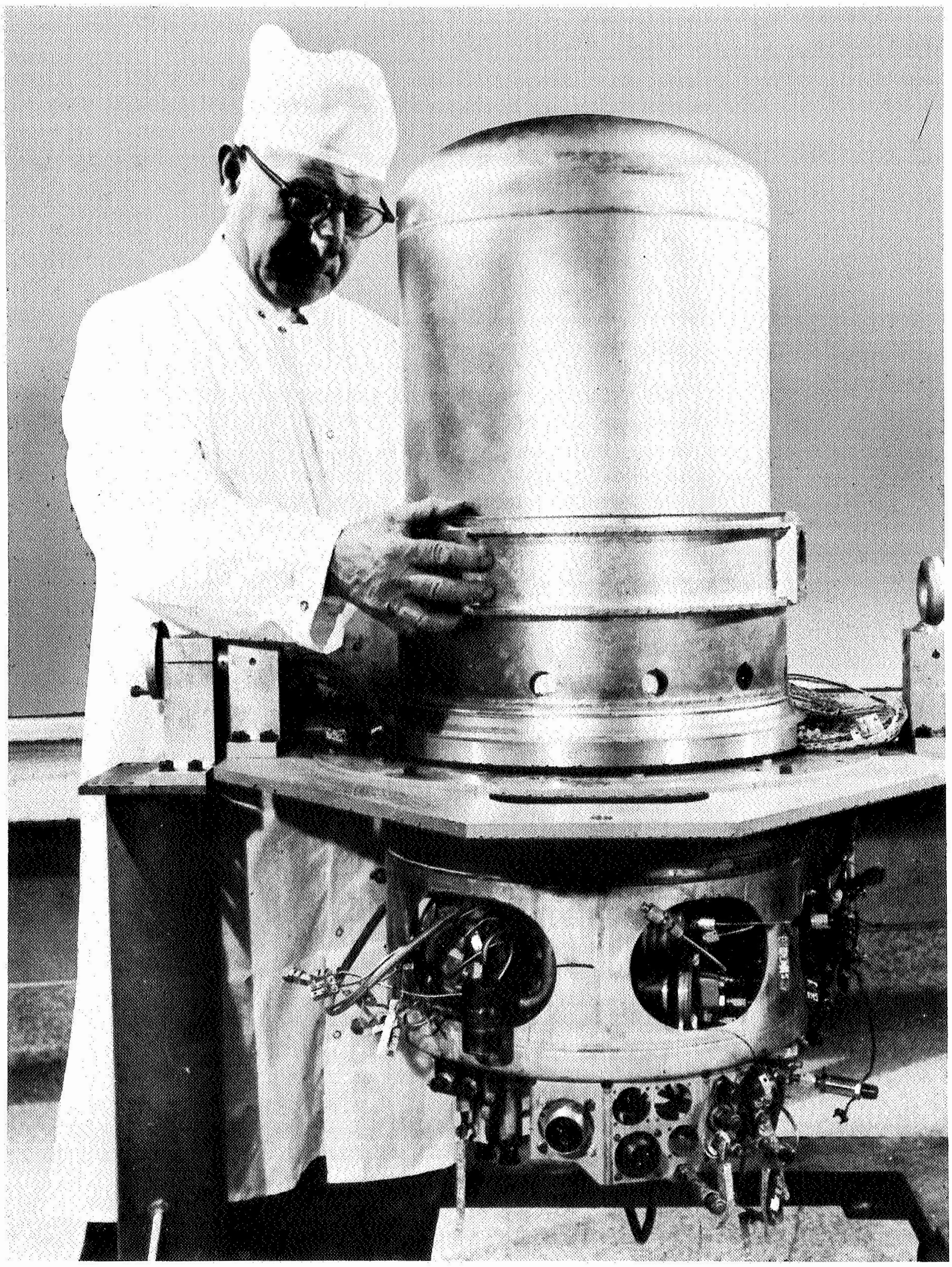


Fig. 3–4. The fuel cell unit for the Apollo spacecraft is being assembled by a technician.

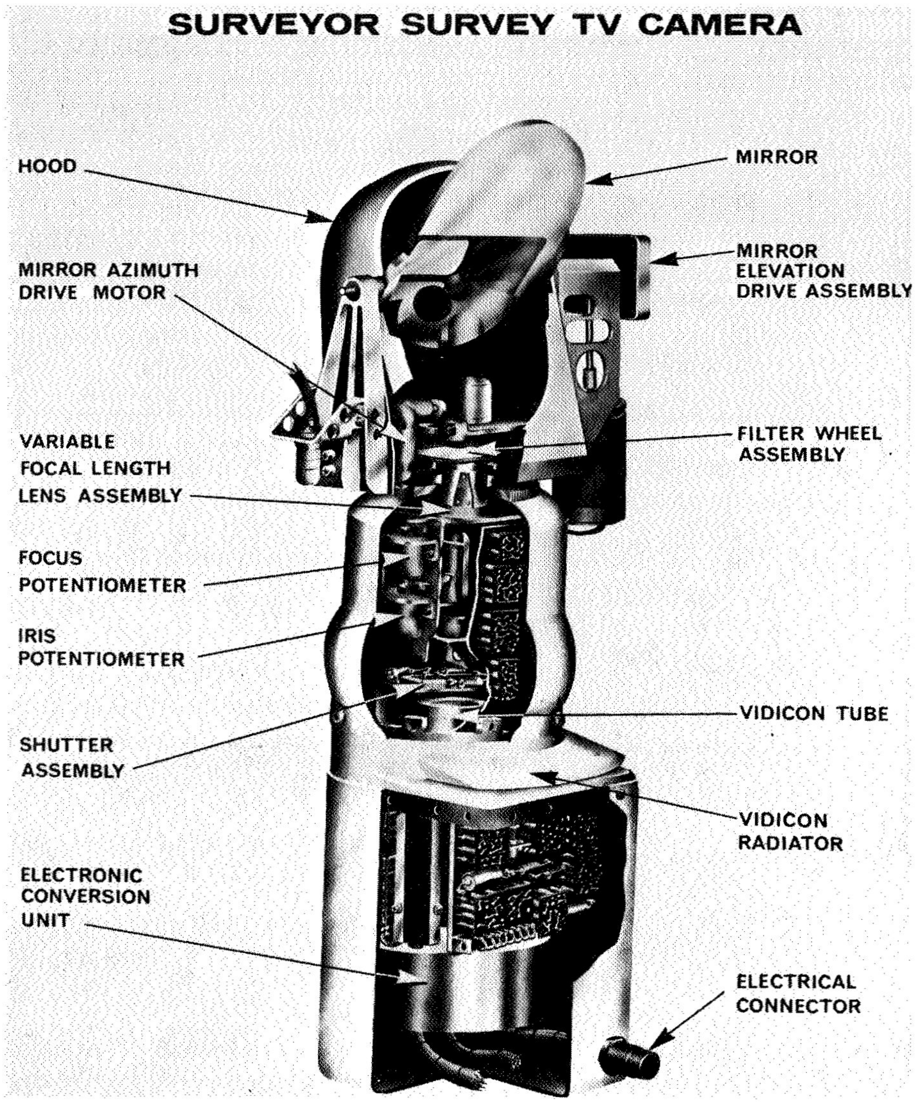


Fig. 3–5. Photography is an important part of the aerospace program.

INDUSTRIAL ARTS AREA

TYPICAL AEROSPACE OCCUPATIONS

photoengraver 971.381, 971.382; electrotyper 974.381; stereotyper 975.782; aerial photograph interpreter 629.188; scientific photographer 143.282; photographic engineer 019.081; photogrammetrist 018.281.

PHOTOGRAPHER, PHOTOENGRAVING (print. & pub.) 971.382. Cameraman; engraving photographer. Sets up and operates camera to photograph drawings, sketches, or other material to produce negatives for transfer to printing plates or rollers: Mounts copy on holder, alining centerline on copy with centerline on holder. Studies copy and order sheet to determine photographic techniques required to transfer desired effect onto film, according to plate or roller dimensions, type of design, colors in design, and engraving requirements. Computes camera settings required to reproduce sketch to

specified scale according to dimensions of printing plates or rollers. Focuses camera, compensating for differences in size and distortions in copy. Measures opening in back of camera to verify settings, using steel tape. Positions film on vacuum board, closes board against back of camera, and locks board in position. Arranges arc lamps for even distribution of light and exposes film for specified length of time. Removes exposed film from camera and develops film in series of developing, rinsing, and fixing baths. Compares developed film with design to determine whether desired effect has been reproduced. Hangs film on line to dry. When producing negatives for half-tone printing, inserts screen in front of film to reduce copy to dots for reproduction. May process sensitized metal plates for subsequent etching [PHOTOENGRAVING PRINTER].

PHOTOGRAPHIC ENGINEER (profess. & kin.) 019.081. Photographic technologist. Designs and constructs photographic equipment and materials, and solves problems concerning industrial and scientific processes and phenomena by using photographic techniques. Plans setup of equipment and controlled procedure to meet unusual situations. Possesses a technical background in mechanical or chemical engineering and other fields and, in addition, photographic ability. May act as consultant to organizations concerned with problems in fields, such as aerodynamics, ballistics, biology, engineering, and metallurgy.

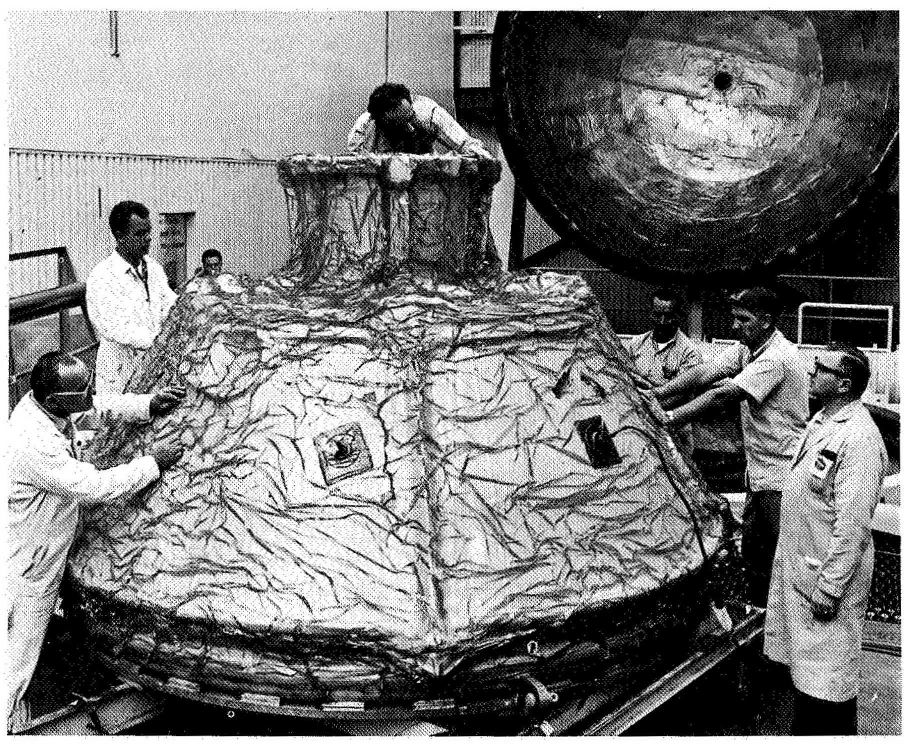


Fig. 3–6. Many applications of plastics technology can be found in the space industry.

INDUSTRIAL ARTS AREA

TYPICAL AEROSPACE OCCUPATIONS

Plastics
Fig. 3-6

Plastics bench mechanic 754.381; plastics fabricator 754.884; electric sealing machine operator 690.885; plastic fixture builder 601.381; plastic toolmaker 601.381; chemical engineer 008.081; chemical laboratory technician 022.281; plastics chemist 022.081.

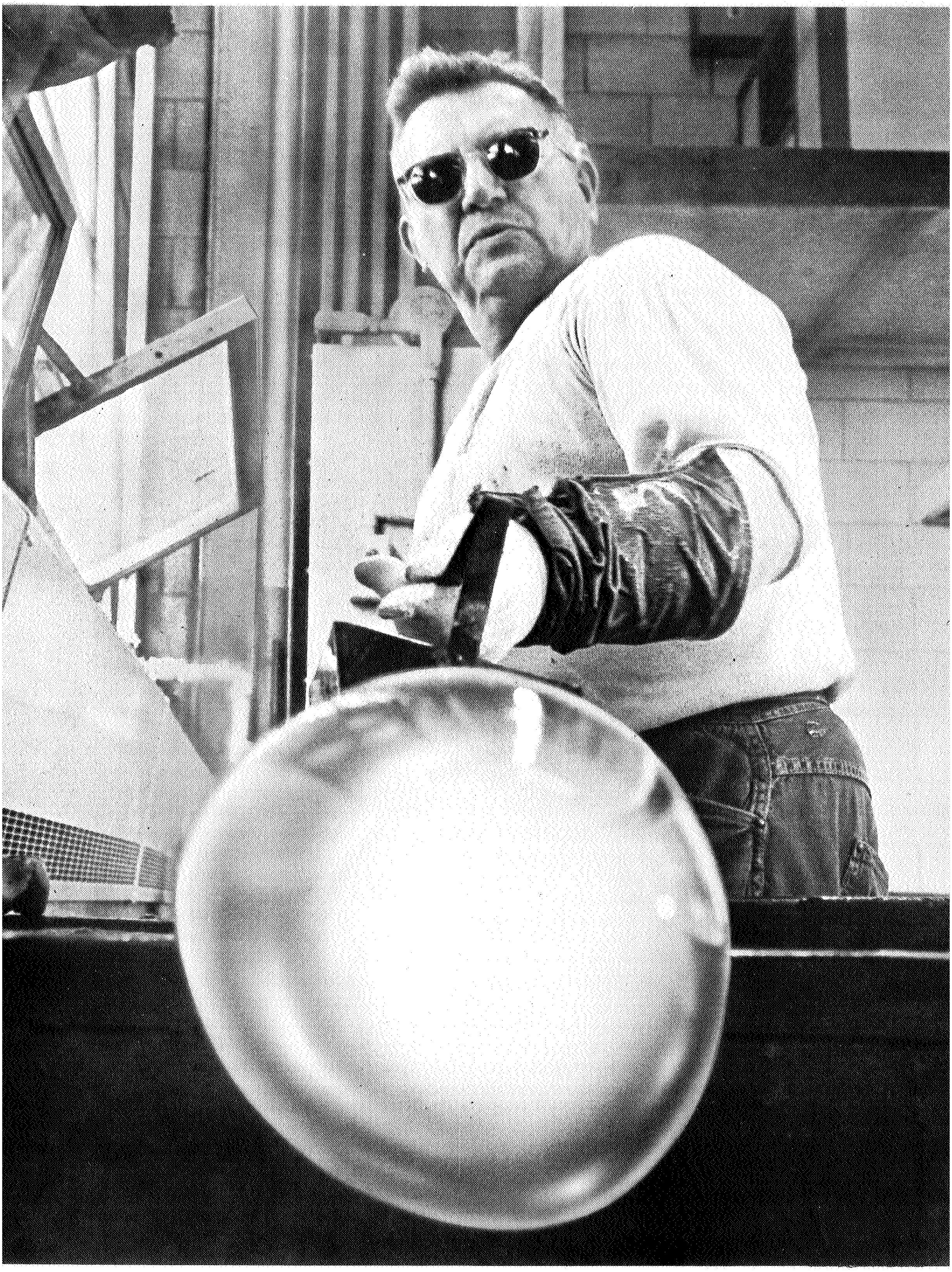
PLASTICS BENCH MECHANIC (aircraft mfg.; fabric. plastics prod.) 754.381. Thermoplastic fabricator. Fabricates and repairs plastic parts and assemblies, such as aircraft or missile canopies, wingtips, and air ducts, according to specifications, using power tools and handtools. Scribes cutting lines on plastic sheets, following template, and cuts out parts, using power saw. Heats parts at specified temperature in oven to facilitate shaping. Shapes heated parts to specifications, using forming block, air mold, or press. Places parts in jig and trims edges, using knife, saw, and grinder. Cuts out cracked or broken areas and cuts new stock to fit, using power saw. Shapes replacement to fit damaged area and tapes or cements it in place. Smooths and polishes parts with rouge to remove Scratches or heats parts over flame until they are pliable and presses scratched edges together. May be designated according to type of plastic used as FIBER WORKER (aircraft mfg.); PLEXIGLAS FORMER; or according to product formed as CANOPY ASSEMBLER (aircraft mfg.). May repair only Plexiglas parts and be designated PLEXIGLAS REPAIRMAN.

PLASTICS FABRICATOR (aircraft mfg.) 754.884. Fabricates plastic accessories, trim, and structural parts of aircraft and missiles by performing any combination of the following tasks: Cuts glass cloth to size, following template or blueprints, using cutting machine, scissors, and knife. Impregnates cloth by dipping it in plastic solution or feeding cloth between rollers of impregnating machine. Places layers of impregnated cloth on mold and presses cloth to fit contours of mold. Slits cloth with scissors or knife and fits and laps ends. Rubs cloth with fingers or scraper to smooth surface and remove air pockets and excess plastic. Encases coated mold in plastic bag and installs air valve. Attaches vacuum line to air valve and turns pump handle to collapse bag and draw it tightly over layers of cloth to form solid lamination. Disconnects vacuum line and places laminated unit in oven. Adjusts oven thermostat to regulate temperature for specified curing time.

Ceramics
Fig. 3-7

Glass lathe operator 674.782; glass blower 674.782; crystal grinder 726.884; crystal finisher 726.085; infrared oven operator 590.885; hydrogen furnace operator 590.885; exhaust operator 725.884; sealer 692.885; ceramic coater 505.885; ceramic engineer 006.081.

CERAMIC COATER, MACHINE (any ind.) 505.885. Ceramic plater. Tends machine that coats metal objects with ceramic mate-



rial: Places workpiece on rack, observing reflection in mirror below rack to determine when surface to be coated is exposed. Closes machine door and presses button to start rack revolving and initiate coating cycle. Observes gages and turns valves to maintain specified flow through coating nozzle. Fills reservoir with ceramic material and turns valves on hydrogen supply tanks to maintain flow of gas to machine. Removes coated parts, blows away excess material with airhose, and places parts in tote box.

CERAMIC ENGINEER (profess. & kin.) 006.081. Conducts research, designs machinery, develops processing techniques, and oversees technical work concerned with manufacture of ceramic products: Oversees testing of physical, chemical, and heat-resisting properties of materials, such as clays and silicas. Analyzes results of test to determine combinations of materials which will improve quality of products. Conducts research into methods of processing, forming, and firing of clays to develop new ceramic products, such as ceramic machine tools, refractories for space vehicles, and for use in glass and steel furnaces. Designs equipment and apparatus for forming, firing, and handling products. Coordinates testing activities of finished products for characteristics, such as texture, color, durability, glazing, and refractory properties. May specialize in one branch of ceramic production, such as brick, glass, crockery, tile, pipe, or refractories. May specialize in developing heat-resistant and corrosion-resistant materials for use in jet and rocket propulsion and in the nuclear energy field.

Woods
Fig. 3–8

Patternmaker 661.281; modelmaker 693.381; mock-up man 693.381; modelmaker 661.380; experimental display builder 739.381; structural painter 840.884; aircraft painter 845.781.

MODEL MAKER (aircraft mfg.) I. 693.381. Constructs aircraft models to scale according to specifications, using woodworking and metalworking machines and handtools: Lays out work to determine lines and contours for model according to blueprints, rough sketches, or verbal instructions, using trigonometric calculations and principles of model designing for establishing station lines and index points. Marks radius, contour, angle, and dimensions on wood, metal, and plastic materials, using crayon or scriber and measuring instruments, such as rules, calipers, and surface gage. Sets up and operates shop equipment, such as bandsaw, planer, jointer, drill press, wood lathe, table saw, shear, and brake, to shape and form parts, such as nacelles wings and control surfaces, and templates and jigs for fabrication of model. Finishes surfaces, using carving knives, chisel, file, and sandpaper. Drills, countersinks, and reams holes in parts and assem-

Fig. 3–7. Glass and other ceramics materials are used in many ways in the space program. Here a technician is blowing a glass container.

blies for screws, dowel pins, and bolts, using portable power tools. Fits and assembles parts, using glues, bolts, solders, and screws to fasten them together and to join wings, fuselage, and tail sections. May install model in wind tunnel and attach testing instruments. May build models of rockets or missiles and be designated MODEL MAKER, ROCKET.

MOCK-UP MAN (aircraft mfg.) 693.381. Mock-up assembler: mock-up builder. Constructs full and reduced-scale experimental and production aircraft mockups according to specifications, using woodworking and metalworking machines and handtools: Lays out lines and contours of aircraft structures and components on metal, wood, and plastic materials with crayon and scriber, according to engineering drawings, sketches, lofting data, or verbal instructions, using calipers, scales, gages, and trigonometry to define radius angles and dimensions. Sets up and operates shop equipment, such as bandsaw, lathe, planer, jointer, and drill press, to shape parts, such as ribs, empennage, wing, landing gear, skin, and floor, according to layout lines and contours. Drills, countersinks, and reams holes in parts and assemblies for bolts and screws, using portable power tools. Forms frames and bases from plaster, using cutting, shaping, and finishing tools. Grinds, files, and sands parts to finish them. Alines and fits parts and assemblies, using transit and sight level. Joins parts together, using bolts, screws, clamps, and/or glue.

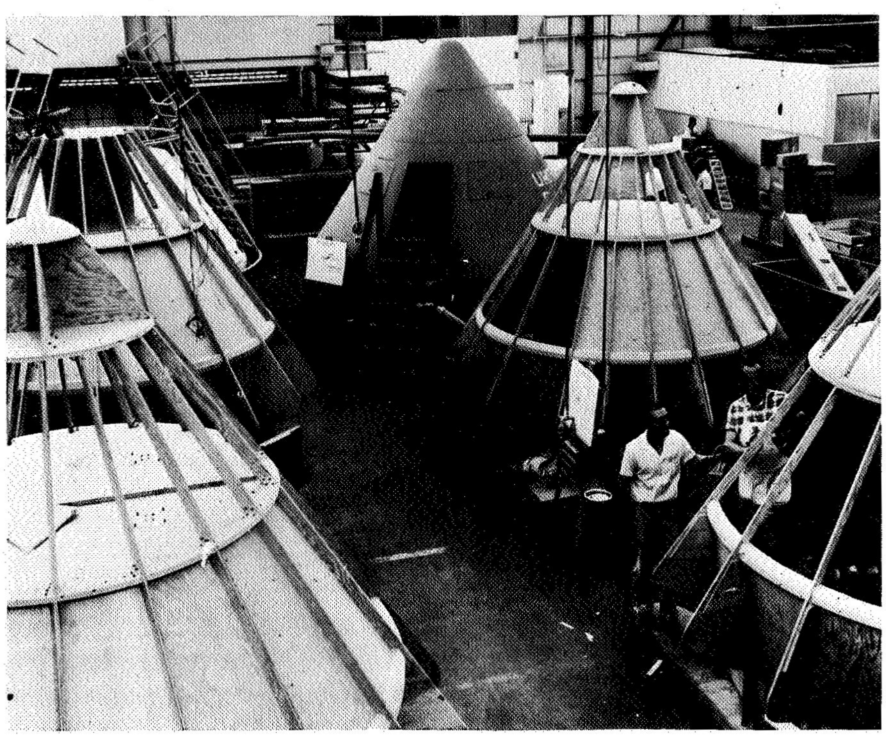


Fig. 3–8. Wood products are used in aerospace contruction.

section 2

section 2

UNIT 1—DESIGN AND DRAFTING

INTRODUCTION

The things that you use and see every day are designed, planned, or invented by people. They don't just happen all by themselves. Men must work at the task of inventing a tool, for example, for many long hours before they finally arrive at a satisfactory solution to the problem. The use of a tool, the possible materials it must be made of, what it will look like, how easy it will be to maintain, these and many many other factors must be considered before the design problem is complete. But just what is design, and what does it involve? Designing is inventing, originating, or creating things to meet some specific need. For example, if there is a need for a device to steer men as they take walks in space or as they move about on the surface of the moon, such devices must be designed, planned, or invented by someone to meet these needs. Note how many kinds of design problems are illustrated in the space suit in Fig. 1–1.

It is equally important to learn to graphically communicate these design ideas to other people who may have to work on them. For example, accurate sketches and drawings must be made of the devices which are designed. It is important also to know something about sketching, rendering, pictorial representation, multiview drawings, dimensioning, and lettering. These are all important parts of visual communication.

DESIGN

The purpose of the design unit is to examine some of the kinds of problems which are associated with space travel. Some sample problems will be presented to you so that you may work on these and try to arrive at some solutions to these problems. But just how are design problems set up and worked on and solved? First of all, it is most important to realize that designing involves creative, individual, original activity. You have to look at a problem openly and without bias. You must not be afraid of completely new, completely exotic, or totally different or unusual possibilities for a solution. Don't be afraid to explore the very strange or unusual possibilities for a product. You will be amazed at how many successful solutions to problems have emerged from a seemingly "crackpot" idea held by some inventor. Don't always look at the negative side of a problem and consider only the reasons why something won't work. Explore it fully, share your ideas with some other people; it just might be that this idea of yours can make a substantial contribution to the solution of the problem.

These steps in the design process are very similar to those which you have learned in your science and mathematics courses which came

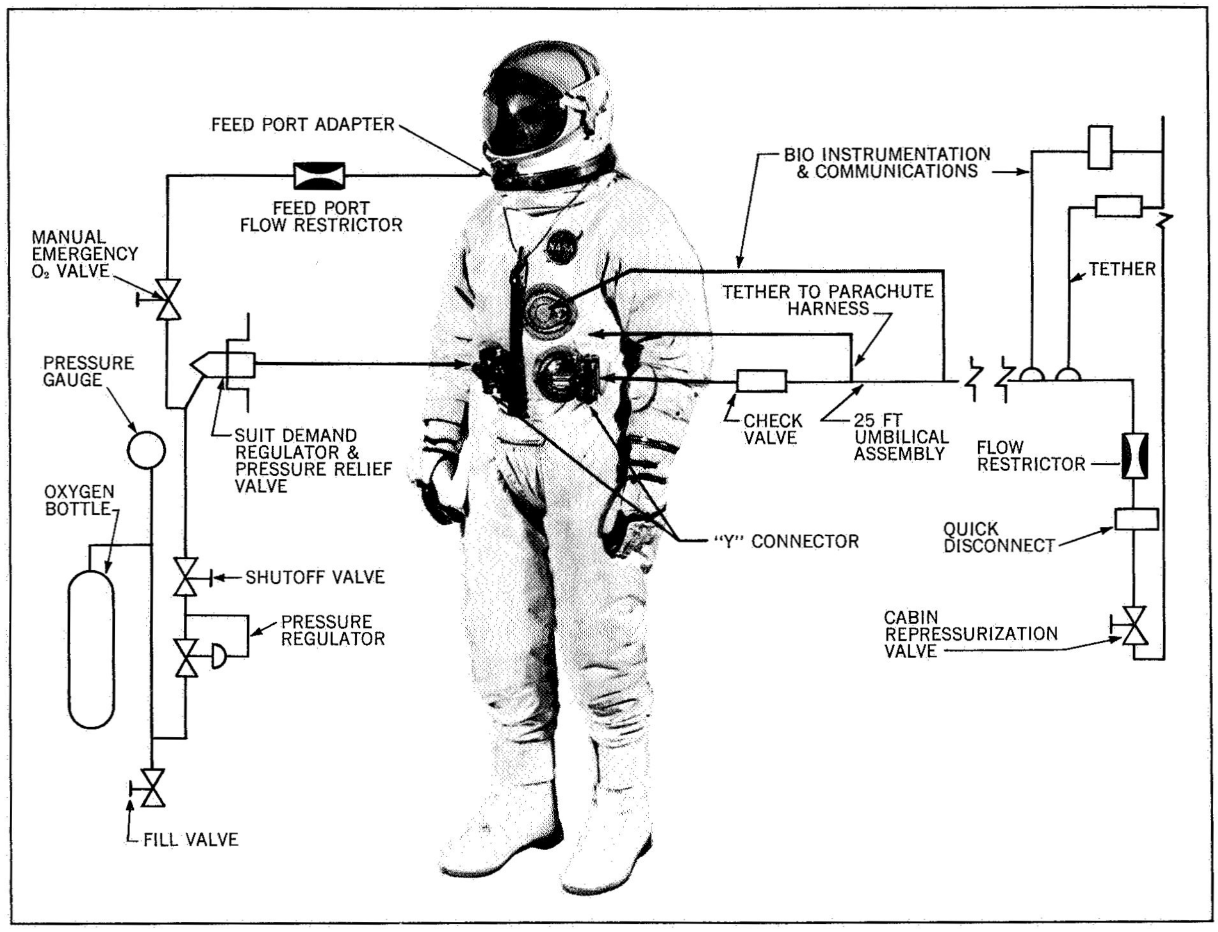


Fig. 1–1.

under the general heading of the scientific method. First of all, you must state your problem or establish your goal. The second step is to think very carefully about the requirements of this problem and to analyze it from all points of view. One must give consideration to questions of *function:* What exactly is this device supposed to do? How long must it be able to function? Questions of *materials* must also be considered, and these are somewhat related to the matter of function. Must this be made of a very very strong material which will last for a long time or can it be a weaker, less expensive material? Must it be waterproof, antimagnetic, or shockproof? Must it be heat resistant? Must it be pliable or firm, fireproof, odorless and tasteless, or just what? These are problems concerning the materials from which the object is to be made and must be given careful consideration in the analysis phase of your design work. A third factor may or may not have any bearing on the problem, and this is simply the matter of *appearance.* Does appearance play a very important part in this product? Generally, we think of appearance of being only important if we have to sell this product to somebody else. For example, you might want to design a chair and come up with a very simple solution, but it is rather ugly to look at. Now in order for this product to be a success, you

would have to reconsider this design in order to make it more pleasing to the user. However, appearance may also be very important to an astronaut in the space capsule. If he is going to be confined to a cramped enclosure for long periods of time in travel through space, it would probably be very important for him to be surrounded by things which are pleasant to look at rather than ugly. So you see appearance can become a very very important factor in your design analysis. On the other hand, the design of a weather satellite would require absolutely no attention be given to its aesthetic appearance since once it has been launched, it will never be seen again. Consequently, its design requirements are purely functional and material. Frequently, however, a purely functional design reflects highly interesting and pleasing contours. Examples of which might be the Saturn system flame deflector or the Apollo command module.

The next step is to prepare some sketches of possible solutions to your problem. Here, particularly, is where the matter of appearance comes into play because you are, in fact, sketching what the thing is going to look like. You also have to try to work out the problems of function in order to make the thing work right and to also give some consideration to the ways in which you might join component parts of the product. Don't be satisfied with one sketch, but prepare a number of ideas and work on these from time to time to try to refine them and and to redevelop some weaknesses you see in them. It is not necessary to spend a great deal of time on colored renderings and very detailed perspective drawings; instead, the simple sketches are as good as anything to communicate and record your design ideas. The next phase of your work might very well involve some simple experimentation or trying out some of these ideas in materials. Make a model of it, or make a mockup of a part of the apparatus, or, perhaps, you may want to make a full-scale working model that is neither too big nor too

Angular Acceleration Measured by Deflection in Sensing Ring

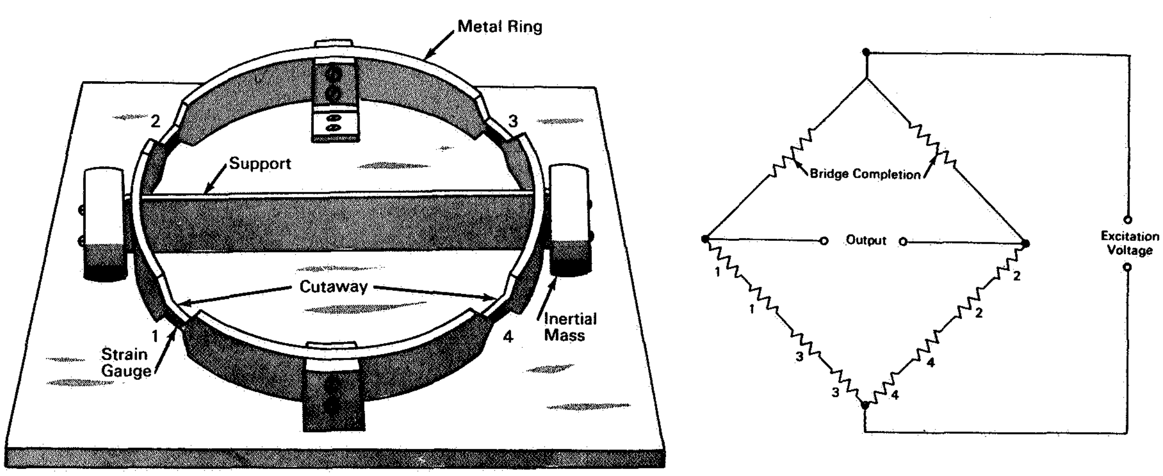


Fig. 1-2.

expensive. Understand that ultimately in all design problems it will be important for models to be made. The last phase of your work is the final solution to your problem. These are working drawings very carefully done which will serve as a guide, a very necessary guide, to the person or persons who might make this device. This is what the design process entails.

You will find many different good examples of aerospace design problems in the *NASA Tech Brief* reports (See bibliography). These briefs are nothing more than technical design problems which were solved by space age engineers and technicians. Fig. 1–2.

SAMPLE PROBLEMS

The following are some suggested design problems dealing with the space age. Work on some of these or plan some of your own.

Problem I. Design tools for repair or assembly operations on vehicles during space flight. When energy is applied to components of a weightless space vehicle, such as turning a bolt with a wrench, the vehicle itself will react by turning if sufficient pressure is required for the operation. This problem can be experimented with by trying to drill a hole in a tennis ball while it is floating in a pail of water. Also consider the problem of collecting the chips. Also the slippage of a tool being used under excessive pressure could result in a serious problem, especially if it is dropped from the user's hand. Further, where a variety of tools are required for a single repair operation, they must be secured by some method while not in immediate use. Consider magnetism and its effects, both positive and negative, as a possible way of retaining the tools.

Problem II. Design a control panel for a moon vehicle which will show the dial indicators, the operating levers, and the buttons and other items on a dashboard. Pay particular attention to human engineering factors and to the matter of not permitting any error in using these controls. For example, there should be some built-in safety feature for the controls which opens sealed cabin doors so that this might not be done accidently. Should different shapes of knobs and levers be used? Study some diagrams of space vehicle interiors for assistance in solving the problem.

Problem III. Design a special device which can be operated from inside the cabin of a moon vehicle for connecting to and disconnecting from a trailer that you might pull behind the vehicle.

Problem IV. Design a simple way of communicating between mechanics while they are assembling things in space. Will radios be the answer or will some special kinds of visual signaling devices be required?

DRAFTING

The following pages are indicative of the kinds of space age applications which can be found for a typical drawing course. These are suggestions; many others can be found by examining the many NASA publications available to teachers and students.

LEARNING UNITS	AEROSPACE APPLICATIONS
DRAWING EQUIPMENT	Typical equipment is used. Stress maintenance and accuracy.
LETTERING	Practice lettering assignments can be selected from any interesting material found in the many NASA publications.
GEOMETRY	Typical bisection and construction problems dealing with geometric forms can be used. Special forms, such as spirals, can be found in many NASA Tech Briefs. See 1C1 for such a spiral.* Fig. 1–3. Ellipses can be constructed to show the orbit of a space vehicle.

Thermal Motor Positions Magnetometer Sensors

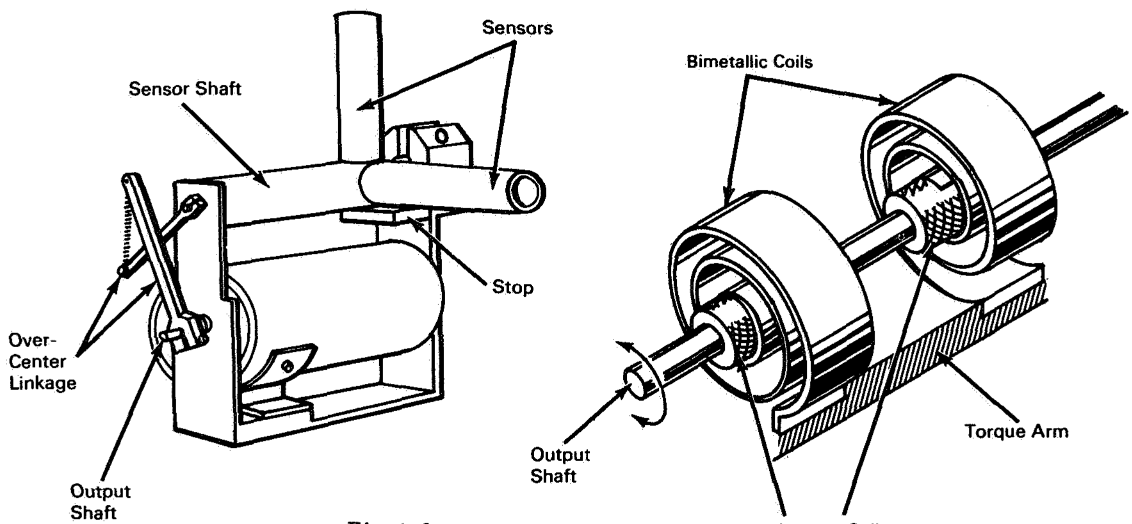


Fig. 1–3.

ONE-VIEW DRAWING	Draw or sketch the following: O-ring tube fitting (1C2) Check valve (1C3) Fig. 1–4. Fluid separator (schematic) (1C4) Nut and sleeve (1C5) Booster rockets (1B1, p. 54) Sun and planets (1A1, p. 44) Space vehicles (1B1, p. 39) Space vehicles (1D1, p. 1)
MULTIVIEW DRAWING	Draw or sketch the following: Mercury-Atlas vehicle (1D2, p. 5) Agena adapter section (1B1, p. 37) Saturn V launch vehicle (1D3) Torque wrench (1C6) Jet airplane (1A2, p. 235) Atlas missile (1A1, p. 22)

**See page 9 for reference code.*

Inexpensive Check Valve Is Installed in Standard AN Fittings

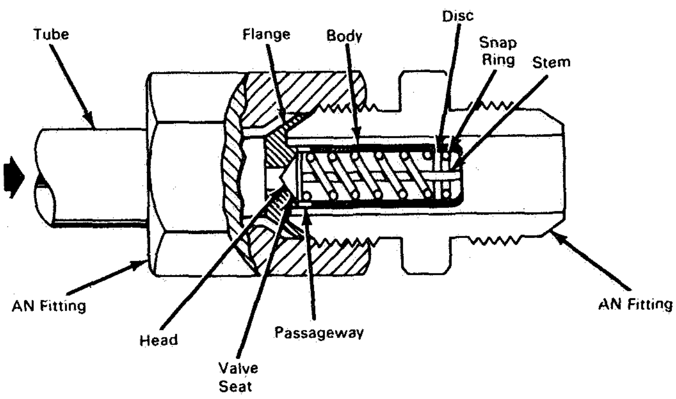


Fig. 1-4.

LEARNING UNITS	AEROSPACE APPLICATIONS
SECTIONS	Draw or sketch the following: Pressure generator (1C7) Fig. 1–5. Friction device (1C8) Fig. 1–6. Electrical connector (1C9) Cryogenic trap valve (1C10) Forming tool (1C11) Space tug (1A1, p. 201)
AUXILIARY VIEWS	The fundamentals of auxiliary view construction found in any good textbook are applicable to aerospace problems. However, try to select problems which involve space activities, such as finding the true length of the base supports of the mobile launcher or the true angles of the braces. Fig. 1–7.
DIMENSIONING	Determine a scale for the above drawings and dimension them accordingly using standard dimensioning techniques. Use metric system dimensions on some pieces. Draw the Mercury-Atlas spacecraft (1D3, p. 5) Titan II. Fig. 1–8.
WORKING DRAWINGS Details	Draw the following: Sextant (1C12) Ground reference instrument (1C13) Fig. 1–9. Calorimeter (1C14) Ionization gauge (1C15) Fig. 1–10. Photographic pyrometer (1C16)

Pressure Transducers Dynamically Tested with Sinusoidal Pressure Generator

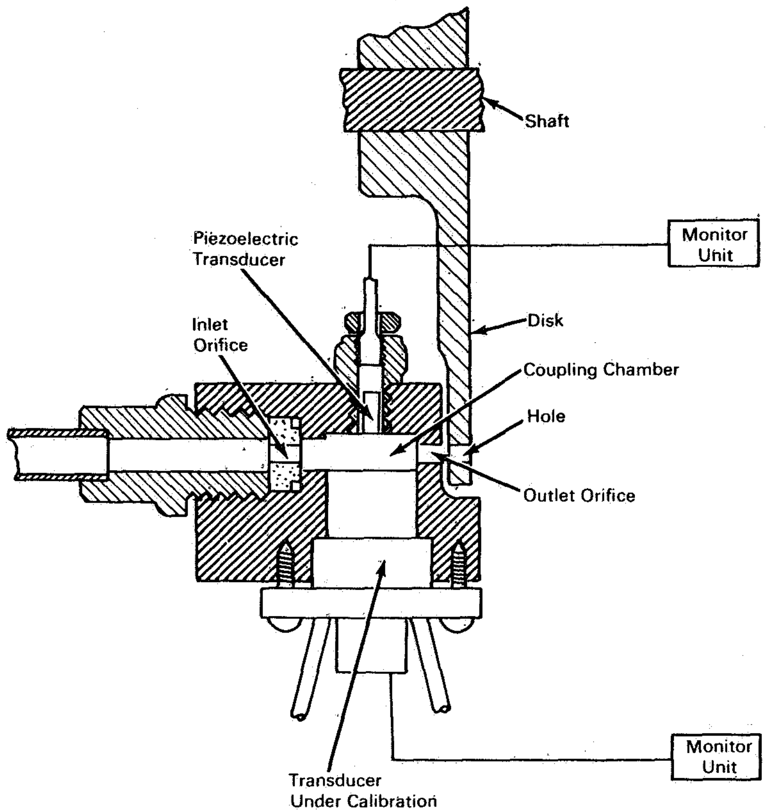


Fig. 1-5.

Friction Device Damps Linear Motion of Rotating Shaft

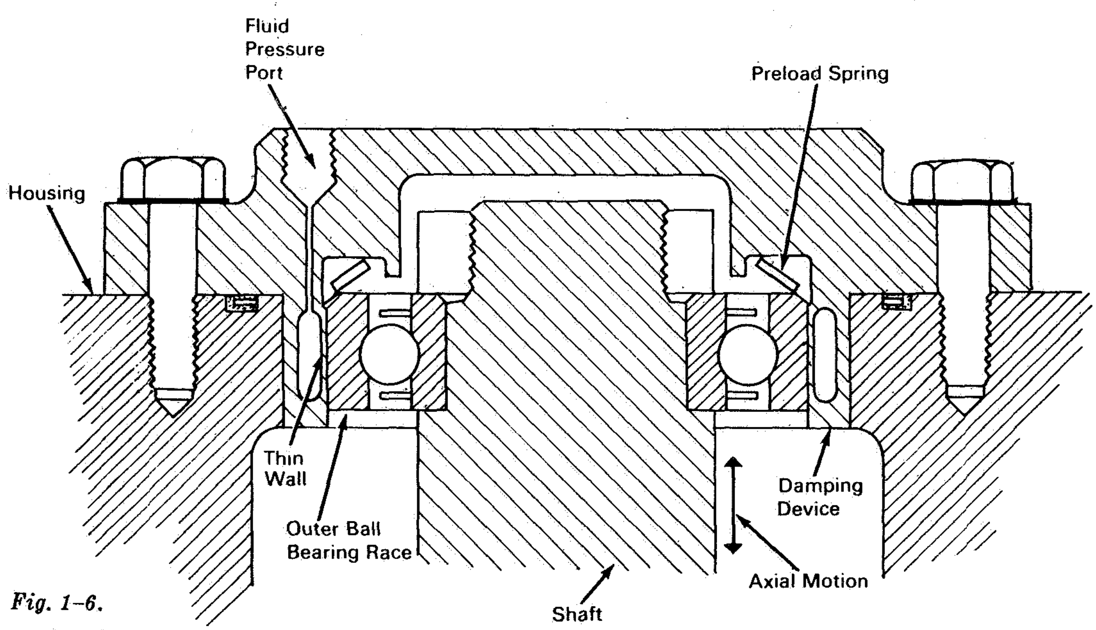


Fig. 1-6.

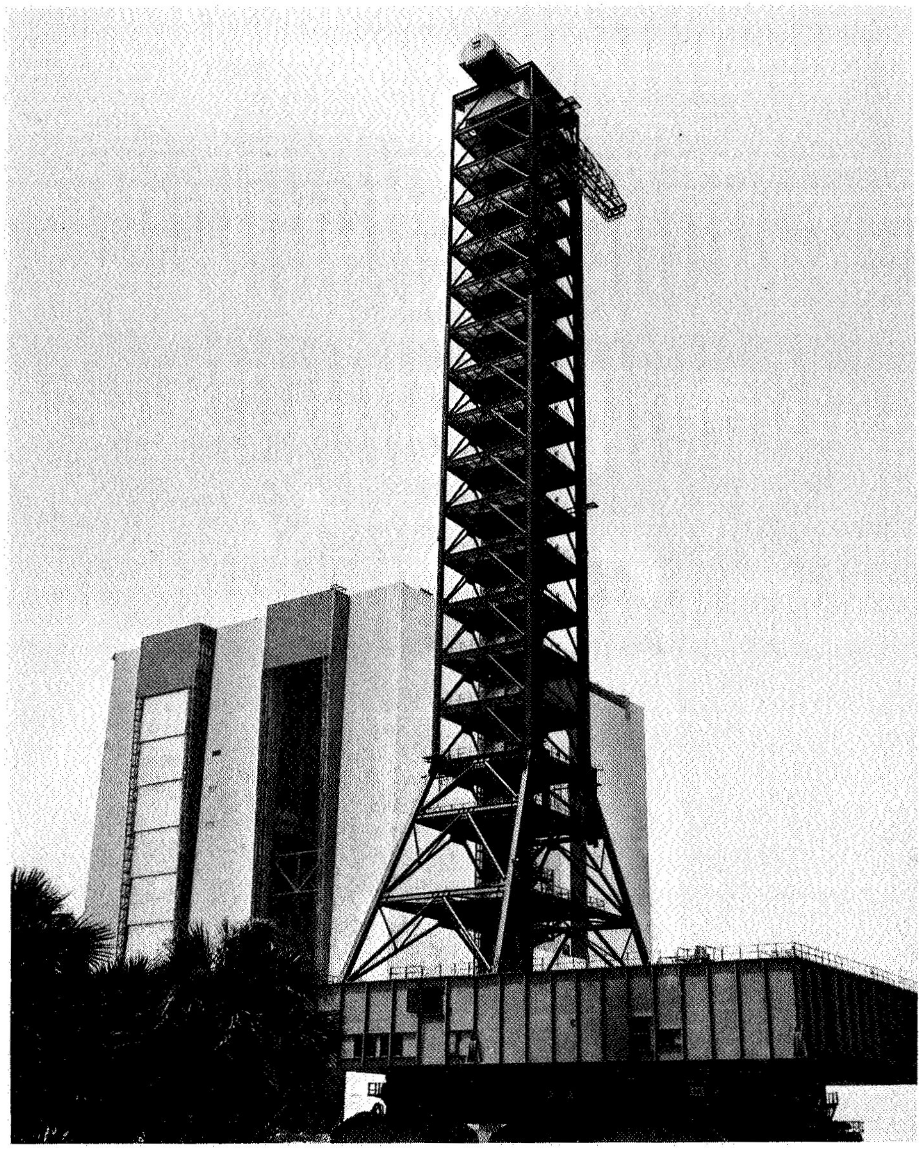


Fig. 1–7.

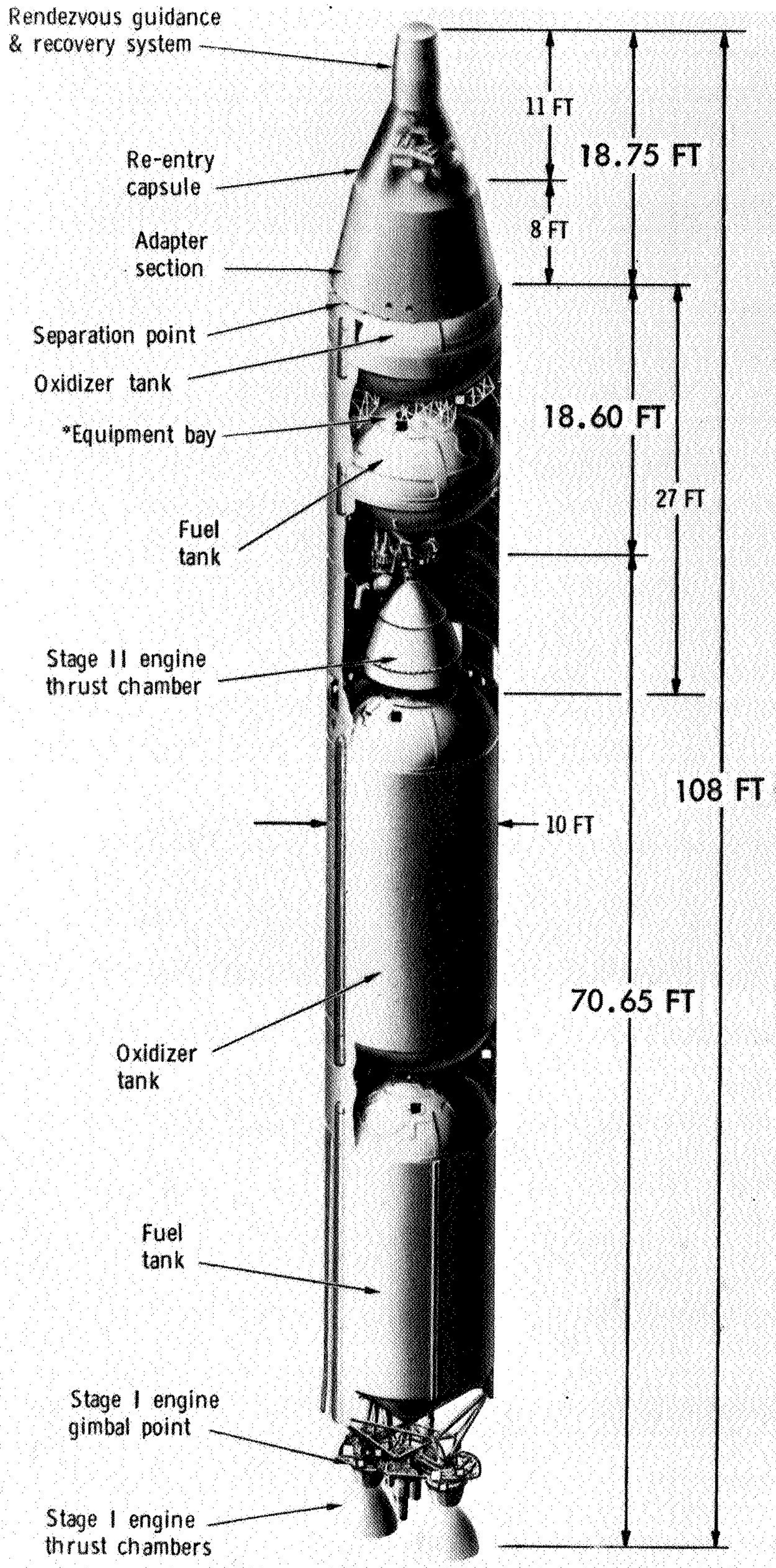
LEARNING UNITS | **AEROSPACE APPLICATIONS**

Assembly

Draw the following:
- Saturn V rocket (1F2) Fig. 1–11.
- T-handle wrench (1C17) Fig. 1–12.
- Hand drill adapter (1C18)
- Nylon shock absorber (1C19)
- Pipe cutting tool (1C20) Fig. 1–13.
- Capacitive system (1C21)
- Cryogenic trap valve (1C22)
- Diagram assembly (1A3, p. 96)
- Gemini mock-up (1D4, p. 3)
- Saturn vehicle (1D5, p. 2)

Fasteners

Draw the following:
- Portable power tool (1C22)
- Modified power tool—torque bolts (1C23)
- Leakproof fittings (1C24)
- Single connector (1C25) Fig. 1–14.
- Chart case (1C26)



*Equipment bay contains:

- Batteries
- Malfunction detection system (MDS) units
- Range safety command control system
- Programmer
- Three-axis reference system (TARS)
- Radio guidance system (RGS)
- Autopilot
- Instrumentation and telemetry system

Fig. 1–8.

Instrument Quickly Transposes Ground Reference Target to Eye Level

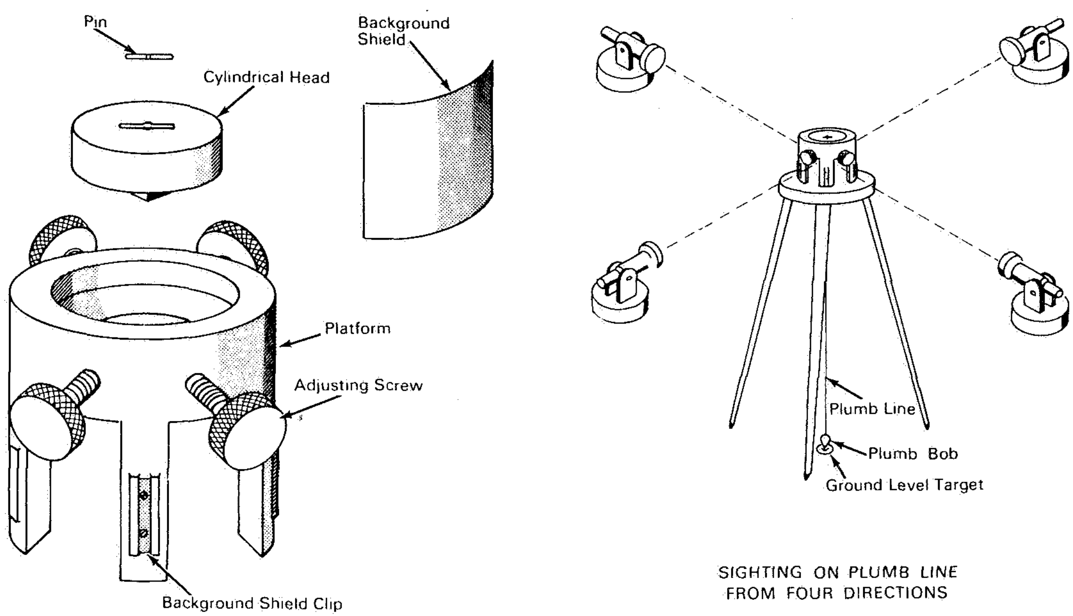


Fig. 1–9.

Cold Cathode Ionization Gauge Has Rigid Metal Housing

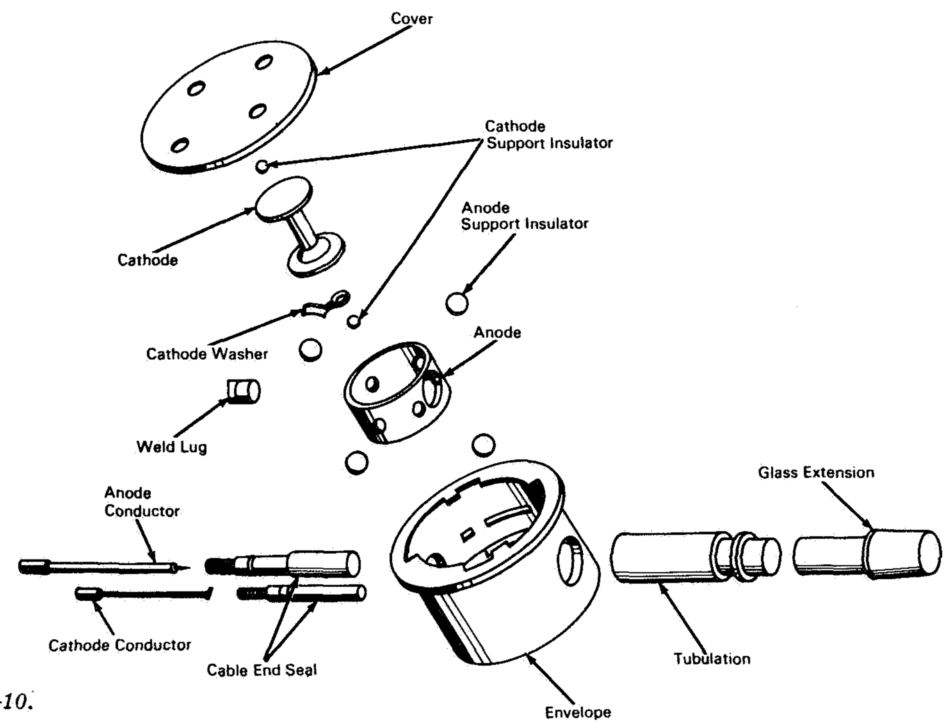


Fig. 1–10.

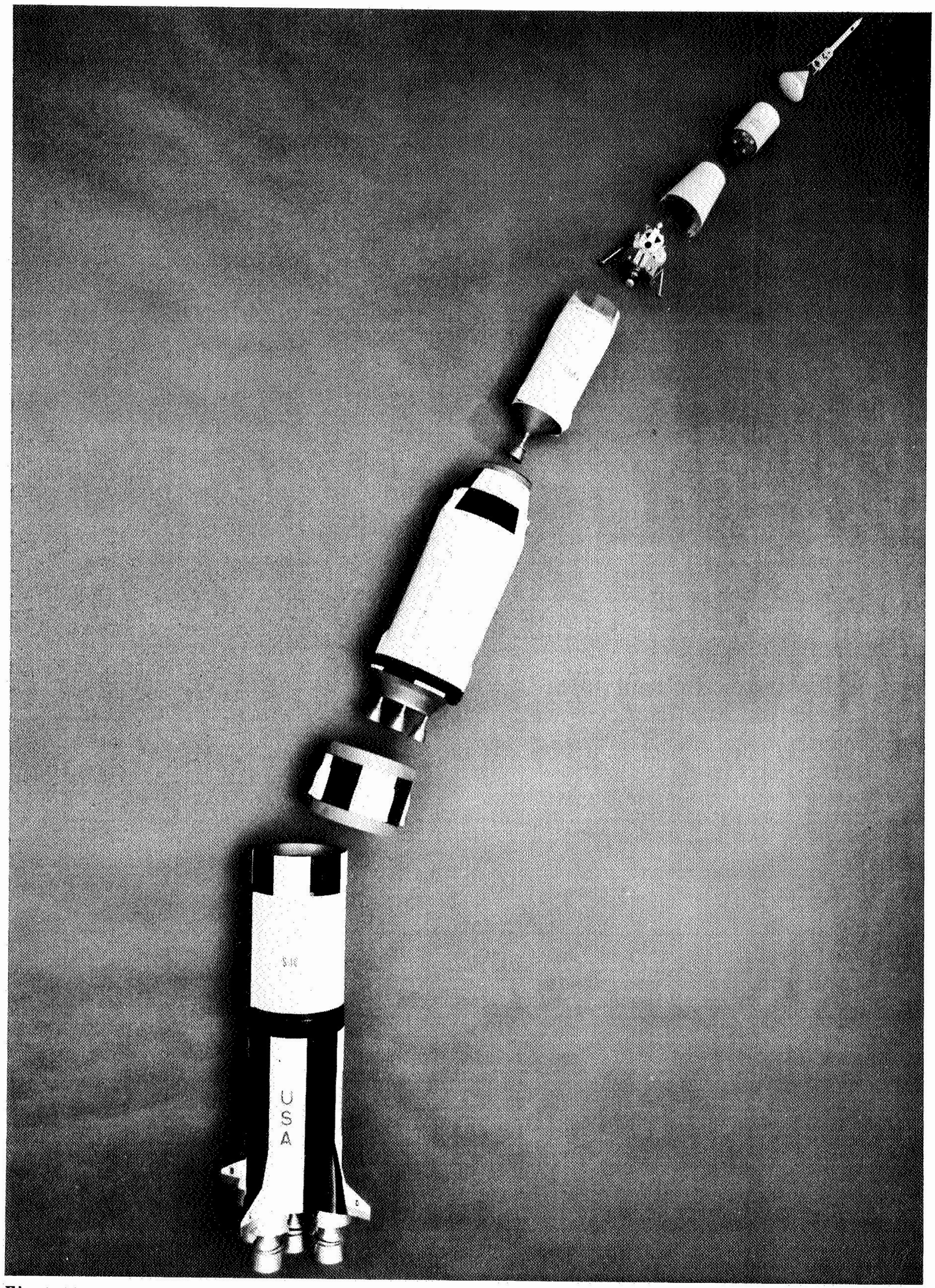


Fig. 1–11.

T-Handle Wrench Has Torque-Limiting Action

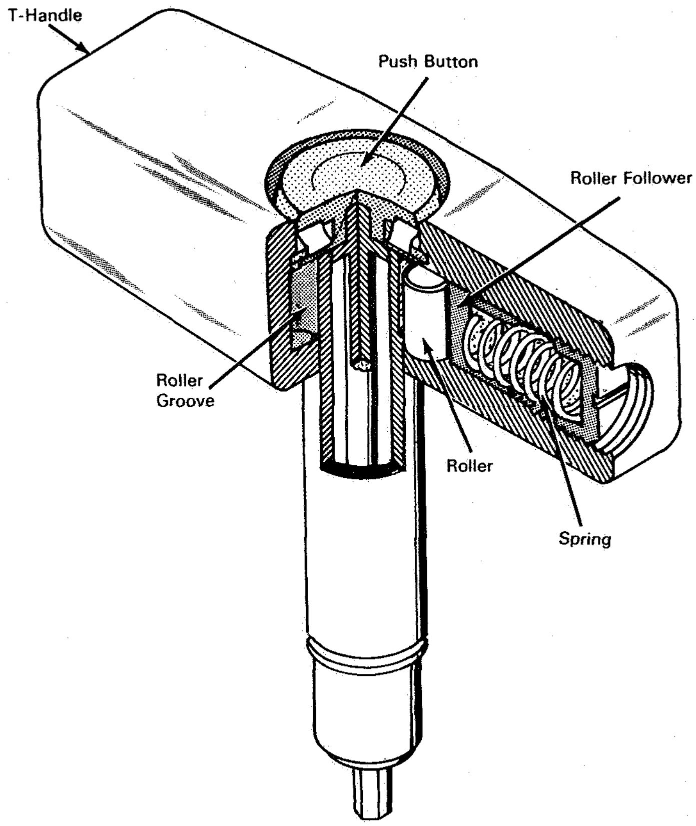


Fig. 1–12.

Pipe Cutting Tool is Useful in Limited Space

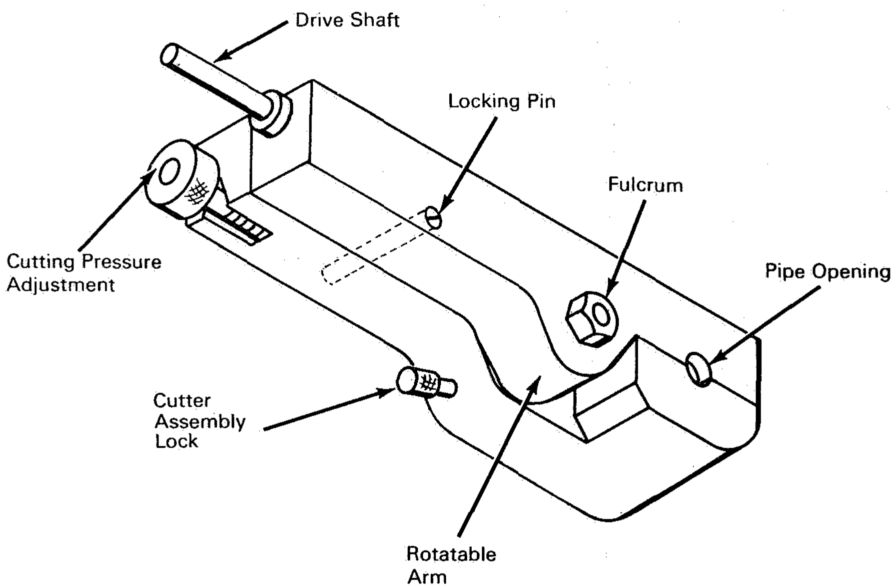


Fig. 1–13.

Single Connector Provides Safety Fuses for Multiple Lines

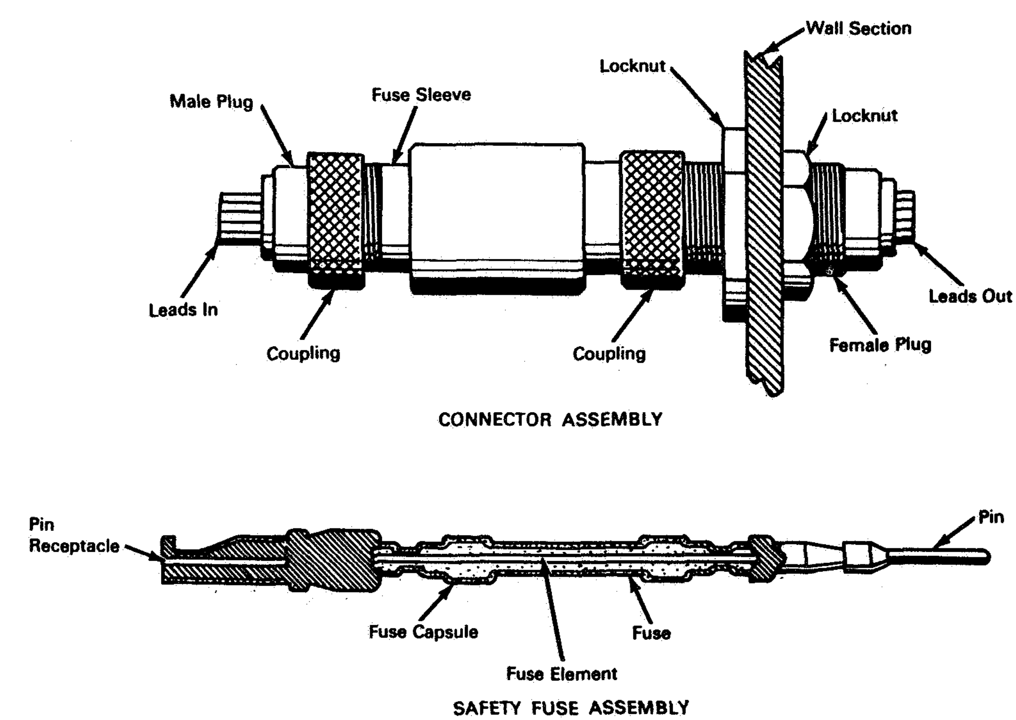


Fig. 1–14.

LEARNING UNITS	AEROSPACE APPLICATIONS
PICTORIAL DRAWING	Draw or sketch the following: Tool (1C27) Fig. 1–15. Plugged shaft (1C28) Shoulder adapter (1C29) Lunar module (1B1, p. 41) Apollo modules (1F3) Fig. 1–16. Gemini spacecraft (1A2, p. 193) Apollo command module (1F4) Fig. 1–17. Vehicles (1A1, p. 167)
SHEET METAL DRAWING (See Sample Teaching Unit)	Draw the following layouts: Rigid boom (1C30) Fig. 1–18. Rolled boom (1C31) Model rocket parts (1F5) Fig. 1–19. Information topics: Forming tubes (1C32) Circular boom (1C33) Fig. 1–20. Permocord grid forming (1C34)

LEARNING UNITS	AEROSPACE APPLICATIONS
ARCHITECTURAL DRAWING	Draw plans for buildings similar to the following: Vehicle Assembly Building (VAB) (1F6) Complex 39 launch pad (1F7) Fig. 1–21.
STRUCTURAL DRAWING	Draw plans for structures similar to the following: Mobile launcher (1F1) Fig. 1–7. Launch gantry (1F8) Information topics:

Wood—Timber tower is used for testing radar installation of space capsule. Metal structure would create interference.

Concrete—Reinforced concrete is used for the structure of launch blockhouses designed to withstand extreme blast pressures. Walls at base 33 ft. thick. Designed to move off foundation rather than collapse.

Steel—Complex steel structures widely used at Cape Kennedy. Tubular steel structure of 50,000 tons for Vehicle Assembly Building, which is the largest in the world. Supported by 16″ pipes driven into ground 160 ft. Saturn V service and umbilical towers are mobile steel structures of 5,000 tons that will be moved 3 miles to launch pad. Corrosion control prompted change from beam construction to tubular construction. Space facilities are located in difficult environments of salt, humidity, wind, and temperature. Tubes present smoother surface which can be more easily sandblasted and painted with vinyls. Radio telescopes, radar, and tracking antennas are lightweight steel structures delicately balanced. Largest is 250 ft. in diameter. (1B1, p. 57)

Improved Tool Easily Removes Brazed Tube Connectors

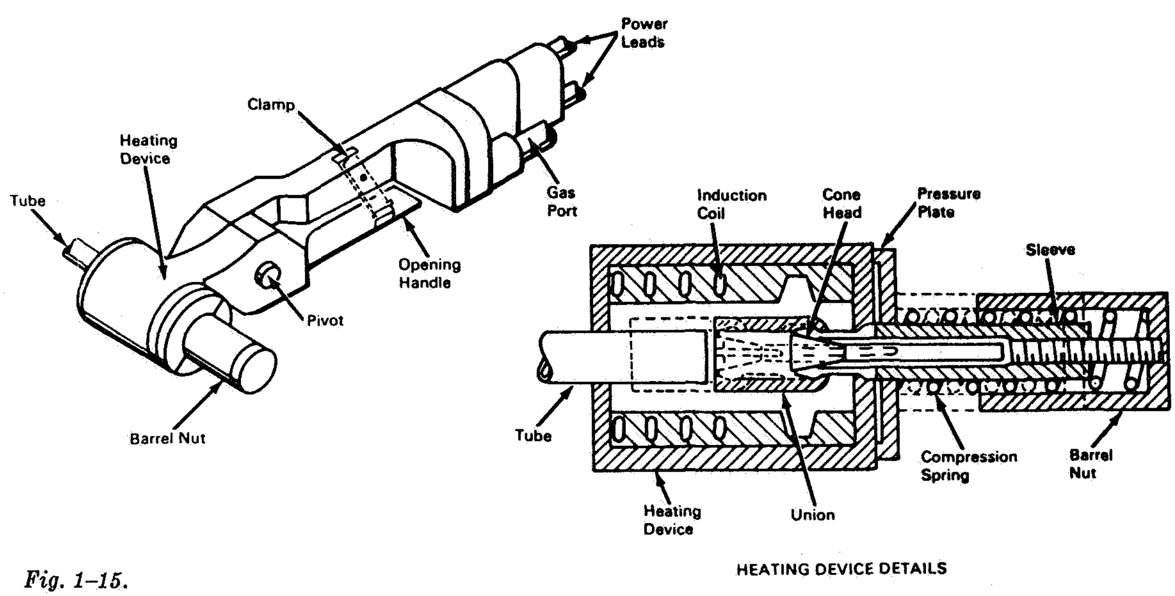


Fig. 1–15.

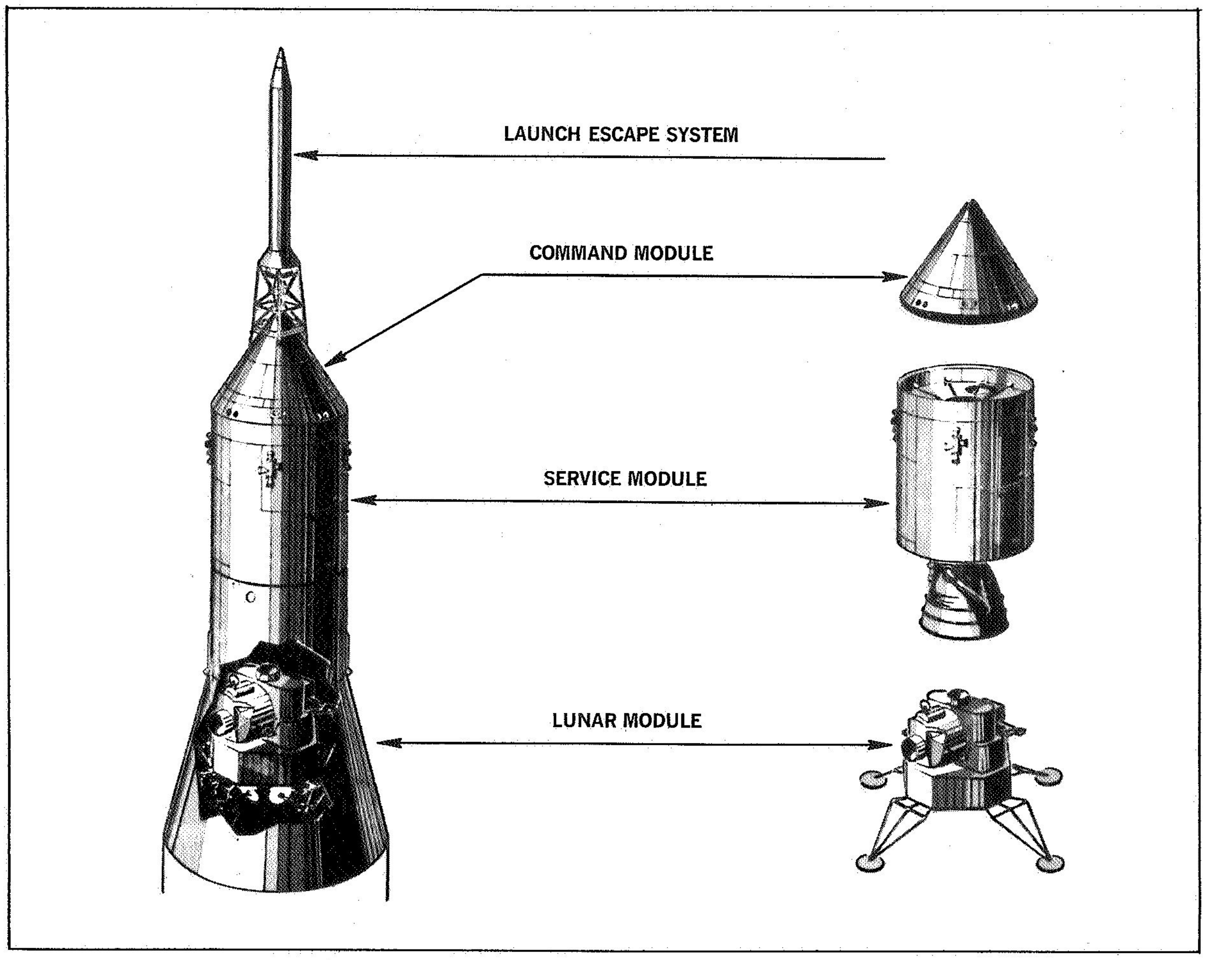
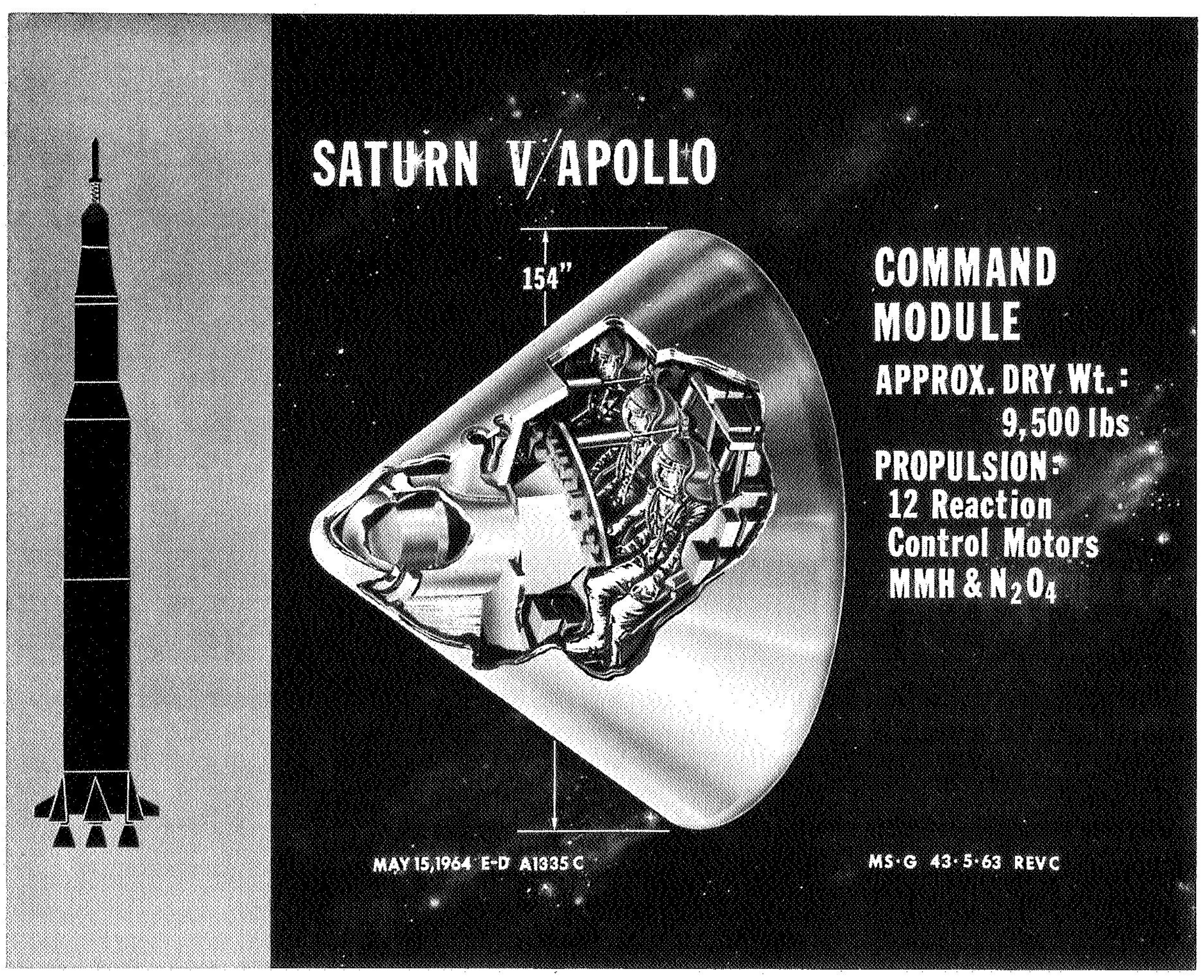
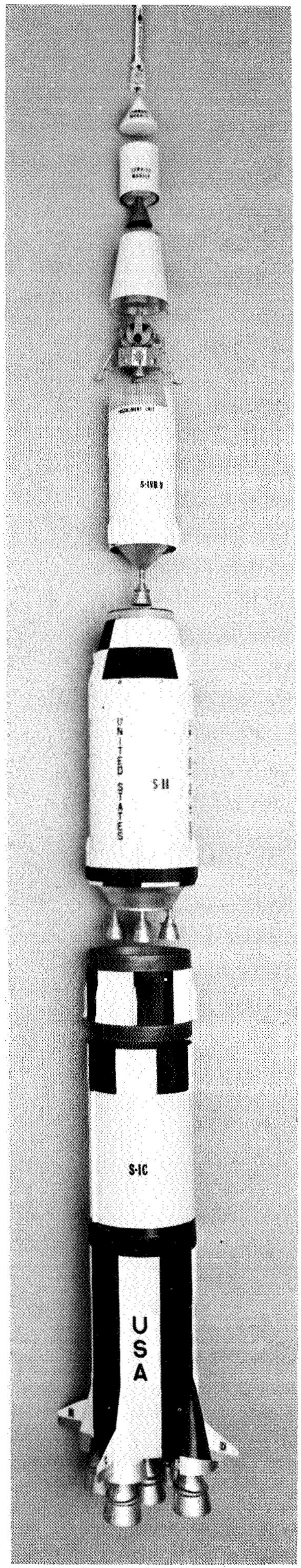


Fig. 1–16.

Fig. 1–17.





Apparatus of Small Size Can Be Extended Into Long, Rigid Boom

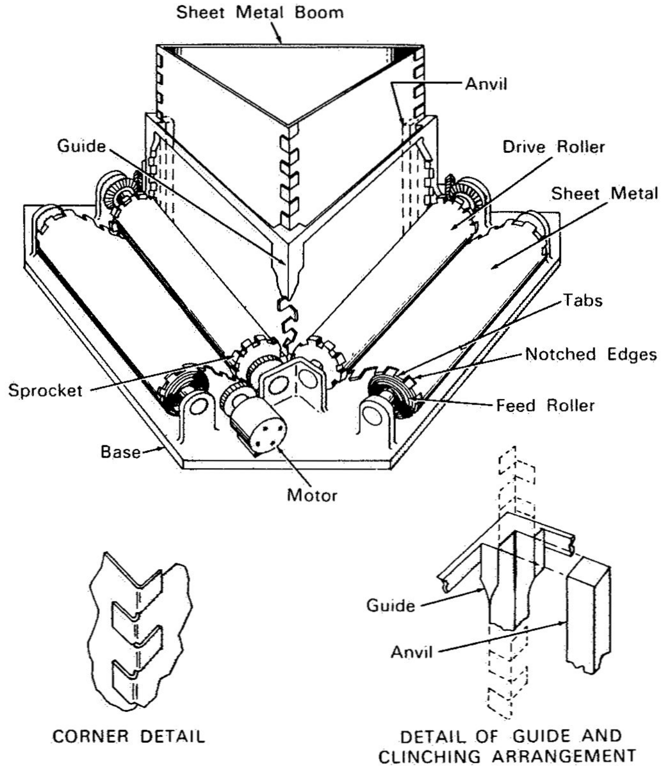


Fig. 1–18.

Coiled Sheet Metal Strip Opens into Tubular Configuration

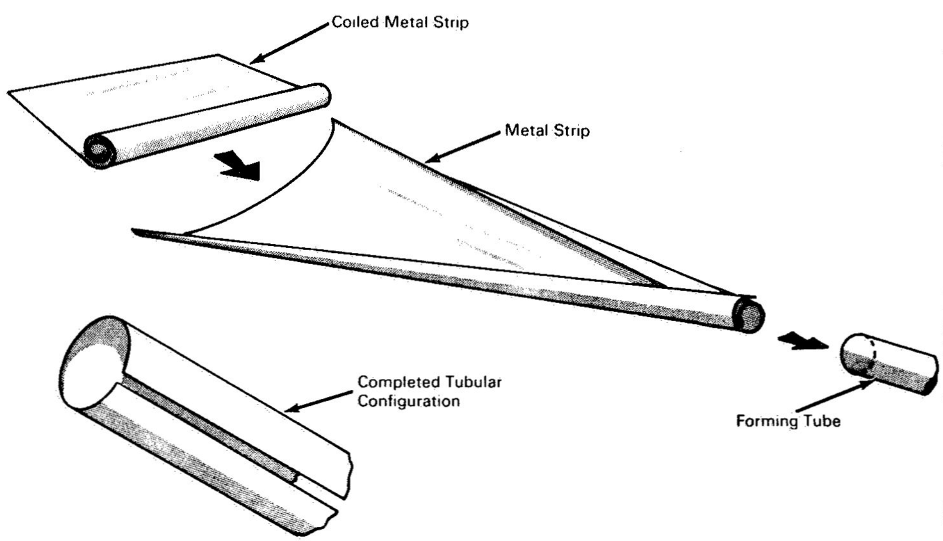


Fig. 1–20.

Fig. 1–19.

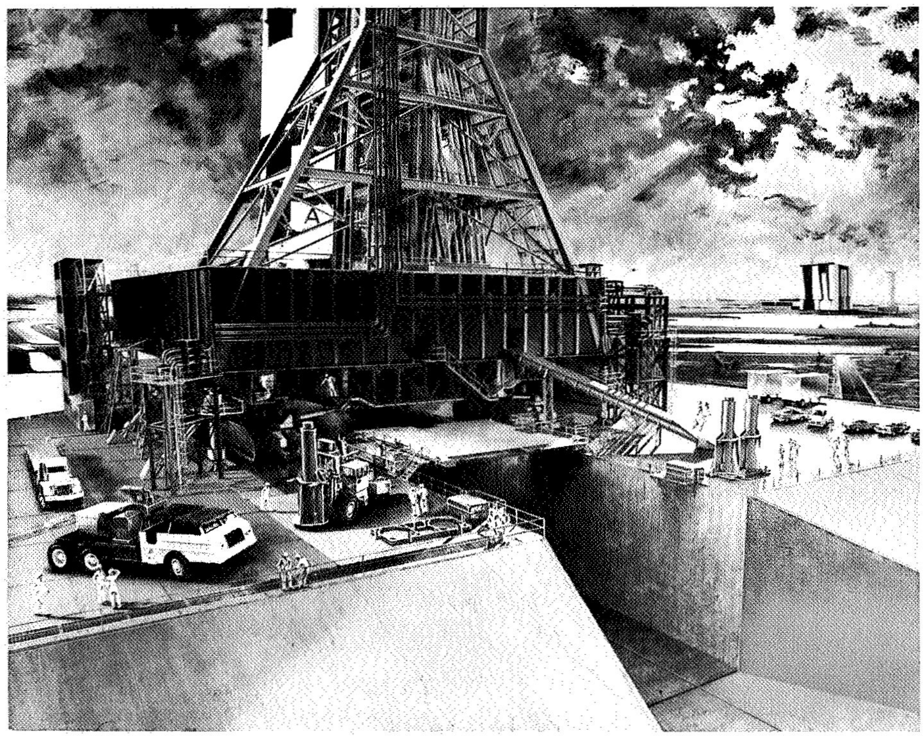


Fig. 1–21.

LEARNING UNITS	AEROSPACE APPLICATIONS
MAP DRAWING	Draw or sketch the following: A weather map (1A1, p. 339) A map of the Merritt Island launch area from the aerial photograph (1F9) Fig. 1–22. A map of the Kennedy Space Center facilities from the aerial photograph (1F10) Fig. 1–23. A map of missile ranges (1A1, p. 333) The Tiros weather map (1B2, p. 41) A moon map from Mariner IV pictures (1B2, p. 45)
ELECTRONIC DRAWING	Draw the following schematics: Gain control circuit (1C35) Bioelectronic device (1C36) Fig. 1–24. Power supply (1C37) Chopper circuit (1C38) Circuit (1C39) Draw the following electro-mechanical devices: Microwave antenna (1C40) Control system (1C41) Skin electrode (1C42) Printed circuits (1C43) Magnetic brake (1C44) Precision gauge (1C45) Fig. 1–25. See Unit 3 of Section 2, "Electricity-Electronics," for related information topics.

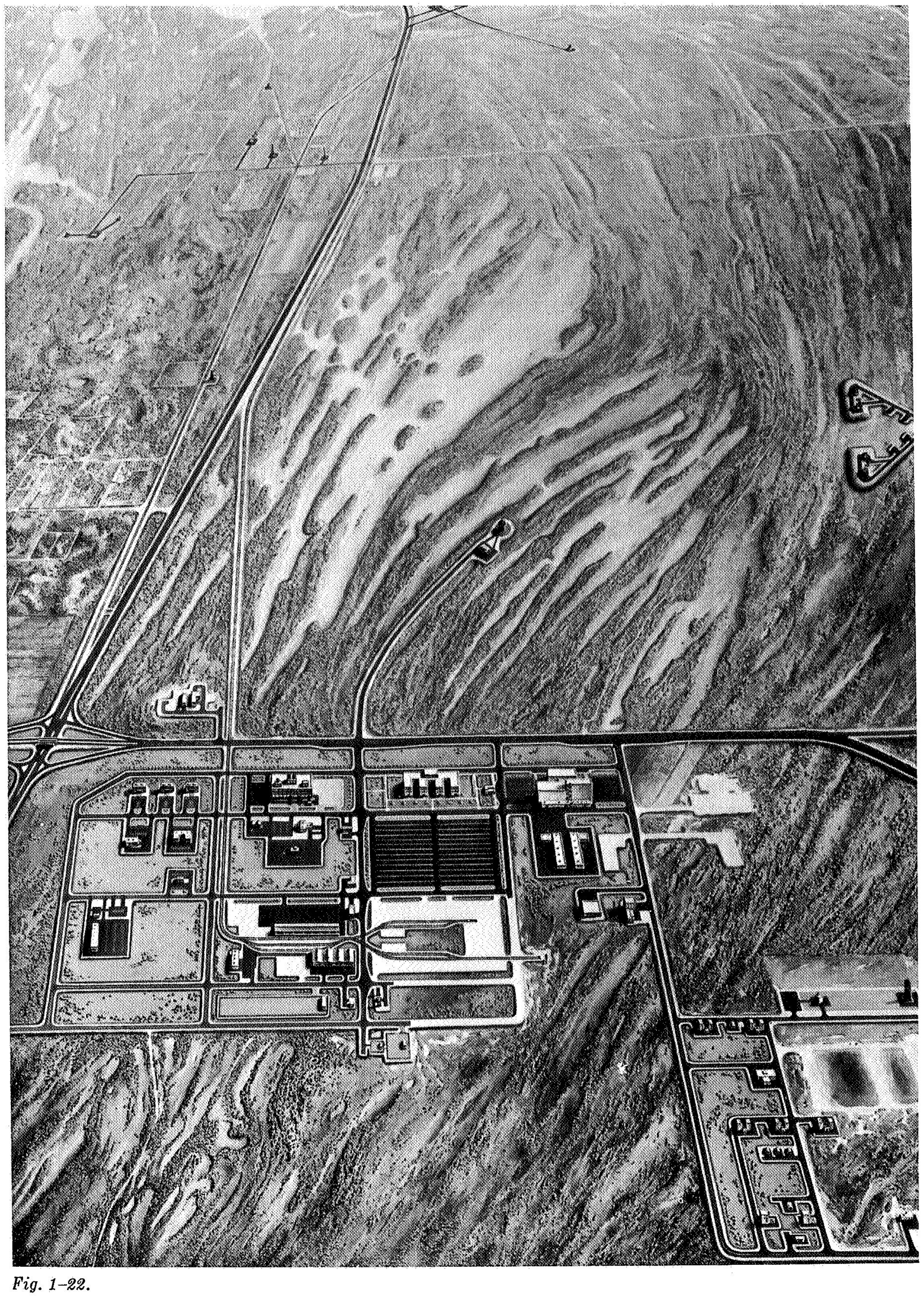


Fig. 1–22.

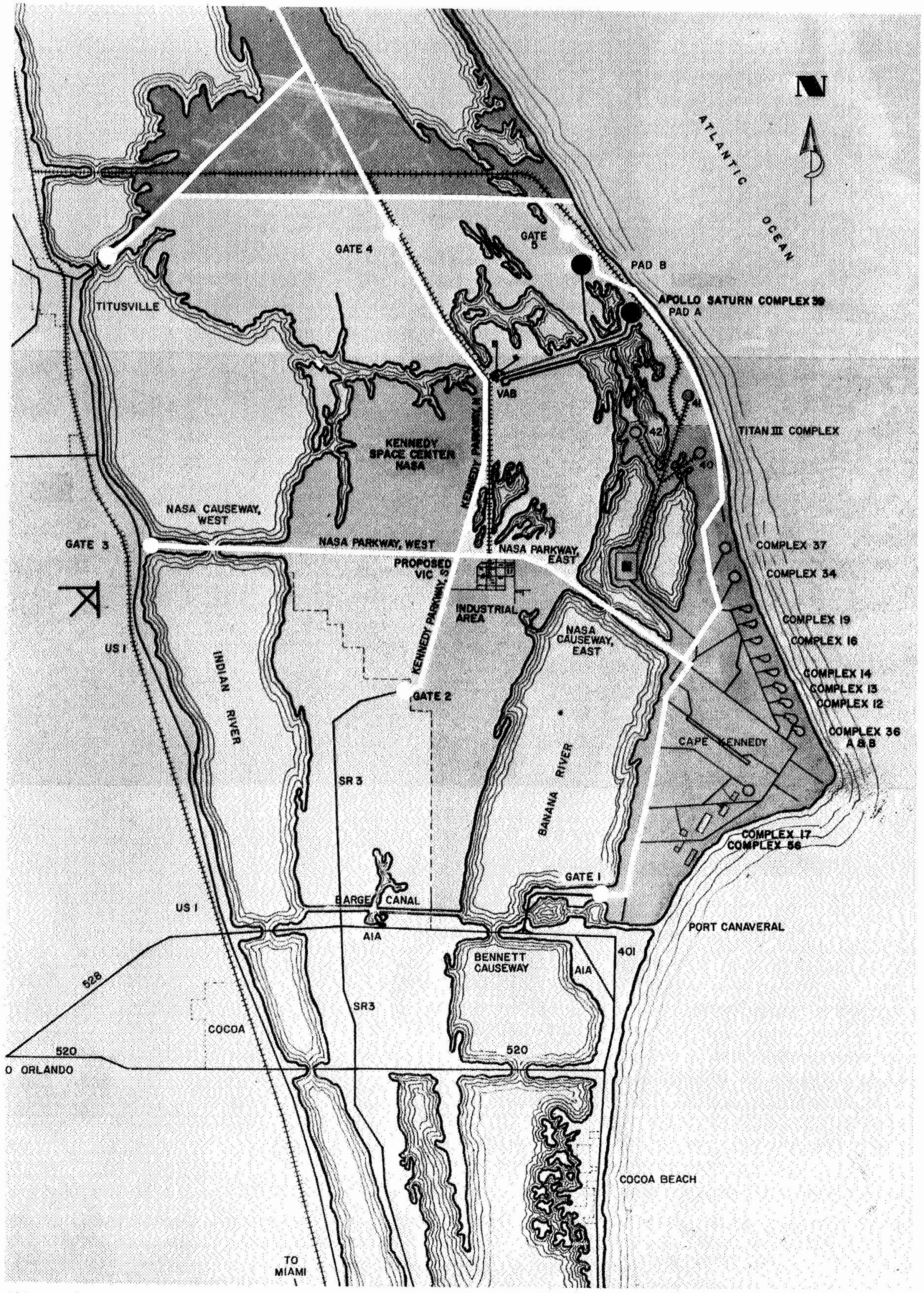

N
ATLANTIC OCEAN
GATE 4
GATE 5
PAD B
APOLLO SATURN COMPLEX 39
PAD A
TITUSVILLE
VAB
41
42
40
TITAN III COMPLEX
KENNEDY SPACE CENTER NASA
KENNEDY PARKWAY, N
NASA CAUSEWAY, WEST
GATE 3
NASA PARKWAY, WEST
NASA PARKWAY, EAST
COMPLEX 37
COMPLEX 34
PROPOSED VIC
KENNEDY PARKWAY, S
INDUSTRIAL AREA
NASA CAUSEWAY, EAST
COMPLEX 19
COMPLEX 16
US 1
INDIAN RIVER
GATE 2
COMPLEX 14
COMPLEX 13
COMPLEX 12
COMPLEX 36 A & B
CAPE KENNEDY
SR 3
BANANA RIVER
COMPLEX 17
COMPLEX 56
GATE 1
US 1
BARGE CANAL
A1A
PORT CANAVERAL
401
BENNETT CAUSEWAY
A1A
528
SR3
COCOA
520
520
O ORLANDO
COCOA BEACH
TO MIAMI

Fig. 1–23.

Miniature Bioelectronic Device Accurately Measures and Telemeters Temperature

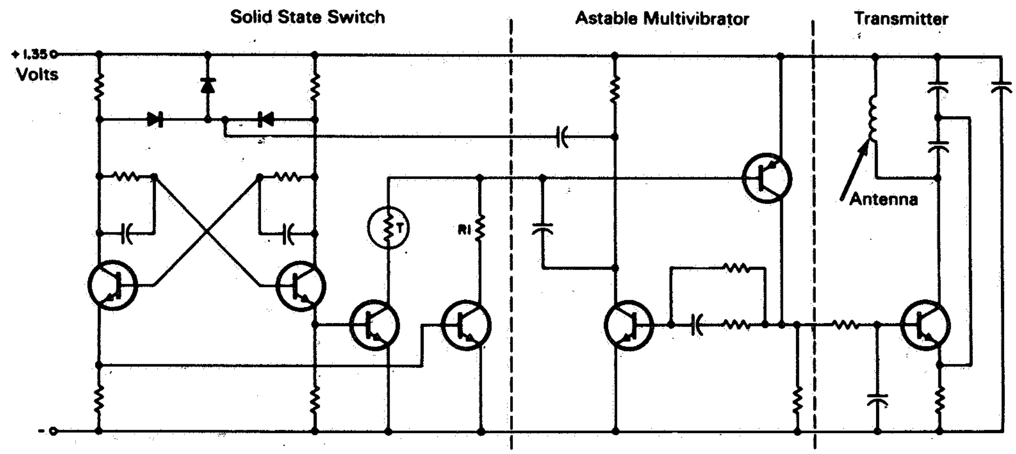


Fig. 1–24.

Precision Gage Measures Ultrahigh Vacuum Levels

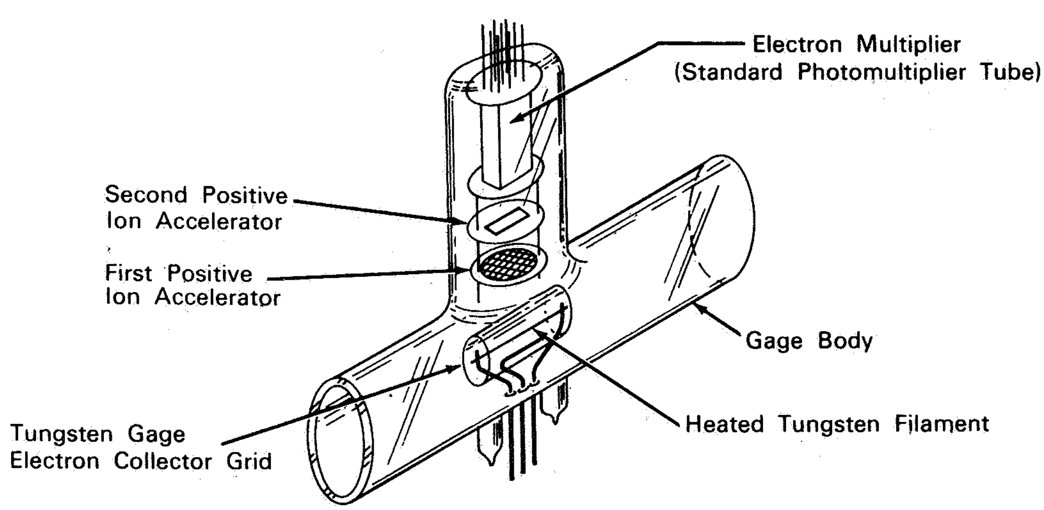


Fig. 1–25.

Tensile-Strength Apparatus Applies High Strain-Rate Loading with Minimum Shock

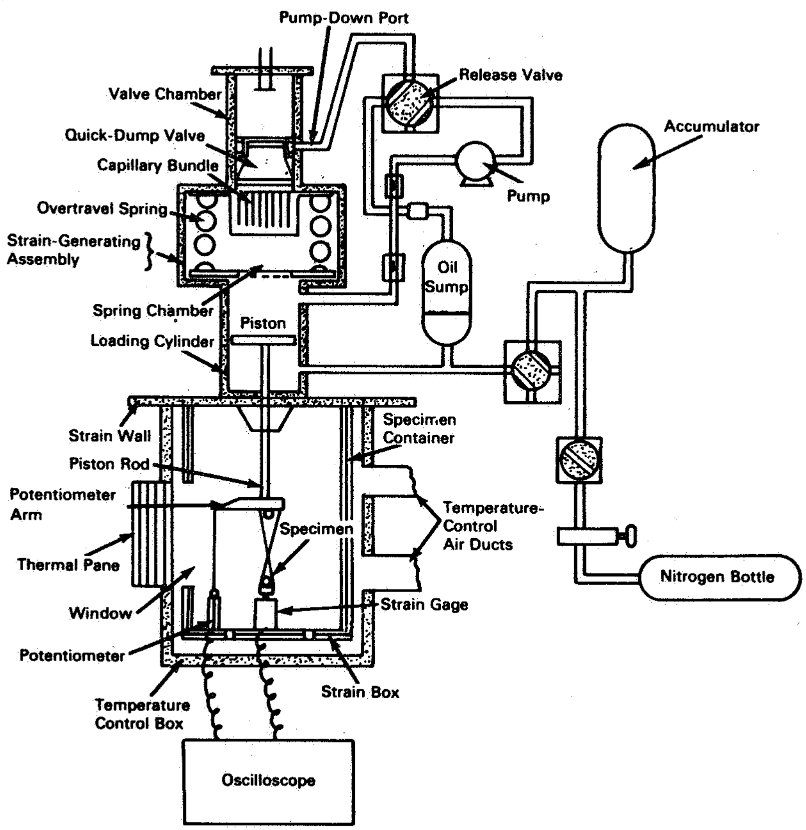


Fig. 1–26.

Transmission System Isolates Pressure Transducer from Severe Environment

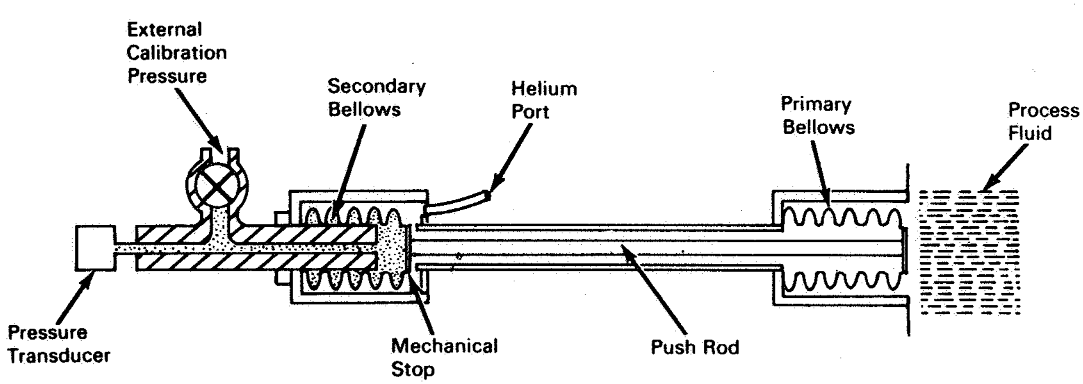
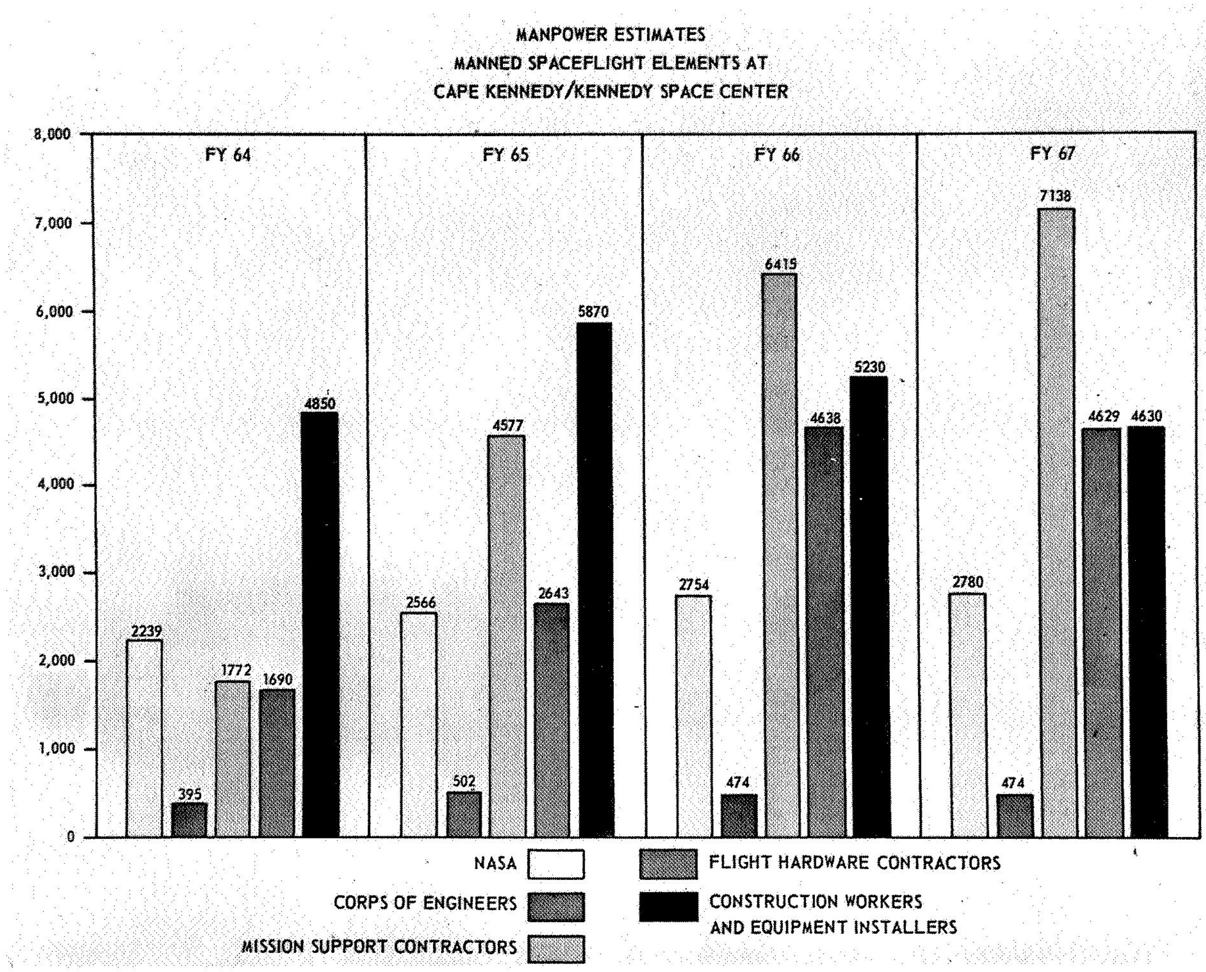


Fig. 1–27.

LEARNING UNITS	AEROSPACE APPLICATIONS
PLUMBING DRAWING	Draw the following plumbing diagrams and assemblies: Gas system (1C46) Tensile strength apparatus (1C47) Fig. 1–26. Regulating system (1C48) Cryogenic trap valve (1C49) Transmission system (1C50) Fig. 1–27. Gas turbine engine (1A1, p. 23)
CHARTS AND GRAPHS	Draw the following charts and graphs: Carbon film data (1C51) Manpower estimator (1F8) Fig. 1–28. Flow chart (1A3, p. 169)



SAMPLE TEACHING UNIT

DESIGN AND DRAFTING

1. Unit: Sheet Metal Drafting
2. Motivation:
   a. Explain our purpose is to learn the uses and how of sheet-metal layout
   b. Show pictures of different uses of sheet metal in rockets (1B1; 1B2; 1D4, p. 8; and 1F5)
   c. Use NASA Technical Briefs to show where specific techniques are used (1C30, 31, 32, and 33)
   d. Show cardboard model of rocket
   e. Show film of specific use of sheet metal in aerospace (1E1)
3. What is Sheet Metal Layout Drafting?
   It is the process of developing sheet-metal parts into what we call stretchouts, which are the sheet-metal pieces laid flat before forming.
4. What it is used for?
   a. Duct systems (show elbow)
      (1) Heating
      (2) Air conditioning
      (3) Vents (stoves, dryers, etc.)
   b. Vehicles
   c. Airplanes
   d. Electronic cases
   e. Rockets
5. What kinds are there?
   a. Parallel-line development
   b. Radial-line development
   c. Transition development
   (Show diagram of each)
6. Relate to class topic.
   Our project for this class will be to make a model rocket from sheet-metal stretchouts.
   The rocket illustrated in the pictures is made up of two types of developments—parallel-line and radial-line.
   a. *Parallel-line.* All cylinder portions of the rocket are made from this type of development.
      Demonstration topic outline:
      (1) Draw full size elevation
      (2) Draw semicircle at bottom of cylinder
      (3) Divide into equal spaces and number them
      (4) Determine circumference of and draw circumference line
      (5) Project over height and draw vertical numbers
      (6) Place tabs where necessary
   b. *Radial-line.* The nose cone and other shaped items are of this type of development.
      Demonstration topic outline:
      (1) Draw front view full size

(2) Draw semicircle at base of front view and divide into any number of equal spaces and number them
(3) Draw arc with radius length of cone size
(4) Draw line from radius center to drawn arc
(5) Lay off equal distances as marked on semicircle
(6) From end points draw line to radius center
(7) Mark off distances from top if necessary
(8) Place tabs where necessary

7. The rocket.
Show parts and stretchout and type of development (See reference 1B3 for dimensions)
a. Nose cone
b. Landing mechanism
c. Control area (cone)
d. Stage 3
e. Instrument area (cone)
f. Stage 2
g. Stage 1

8. Assignment:
From this information and the text materials on developments (1A3, pp. 122–129; 1A1, pp. 251–260) each student will make his his own rocket on heavy construction paper.

9. Evaluation:
Quiz on sheet-metal developments

REFERENCE MATERIALS

DESIGN AND DRAFTING

(Film List—see Appendix II, page 161)

1A1 Feirer, John L. Drawing and Planning for Industrial Arts (Revised). Peoria, Illinois: Chas. A. Bennett Co., Inc., 1963.
1A2 French, Thomas E. and Svensen, Carl L. Mechanical Drawing. New York: McGraw-Hill Book Co., 1966.
1A3 Giachino, J. W. and Beukema, Henry J. Drafting (Third Edition). Chicago: American Technical Society, 1965.
1B1 NASA EP–6 (Revised) Space—The New Frontier, Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. $.75
1B2 NASA EP–29 Historical Sketch of NASA, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.50
1B3 NASA O–741–996 Model Spacecraft Construction, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.50

1C1 *NASA Tech Brief 66–10078
1C2 NASA Tech Brief 66–10020
1C3 NASA Tech Brief 66–10222
1C4 NASA Tech Brief 66–10008
1C5 NASA Tech Brief 66–10180
1C6 NASA Tech Brief 66–10011
1C7 NASA Tech Brief 66–10031
1C8 NASA Tech Brief 66–10030
1C9 NASA Tech Brief 66–10079
1C10 NASA Tech Brief 66–10136
1C11 NASA Tech Brief 66–10001
1C12 NASA Tech Brief 66–10143
1C13 NASA Tech Brief 66–10061
1C14 NASA Tech Brief 66–10058
1C15 NASA Tech Brief 66–10041
1C16 NASA Tech Brief 66–10095
1C17 NASA Tech Brief 66–10065
1C18 NASA Tech Brief 66–10123
1C19 NASA Tech Brief 66–10080
1C20 NASA Tech Brief 66–10102
1C21 NASA Tech Brief 66–10099
1C22 NASA Tech Brief 66–10136
1C23 NASA Tech Brief 66–10145
1C24 NASA Tech Brief 66–10054
1C25 NASA Tech Brief 66–10020
1C26 NASA Tech Brief 66–10050
1C27 NASA Tech Brief 66–10135
1C28 NASA Tech Brief 66–10003
1C29 NASA Tech Brief 66–10077
1C30 NASA Tech Brief 66–10076
1C31 NASA Tech Brief 63–10200
1C32 NASA Tech Brief 64–10011
1C33 NASA Tech Brief 66–10009
1C34 NASA Tech Brief 66–10032
1C35 NASA Tech Brief 66–10014
1C36 NASA Tech Brief 66–10089
1C37 NASA Tech Brief 66–10057
1C38 NASA Tech Brief 66–10002
1C39 NASA Tech Brief 66–10113
1C40 NASA Tech Brief 66–10034
1C41 NASA Tech Brief 66–10229
1C42 NASA Tech Brief 66–10039
1C43 NASA Tech Brief 66–10118
1C44 NASA Tech Brief 63–10596
1C45 NASA Tech Brief 66–10073
1C46 NASA Tech Brief 63–10597
1C47 NASA Tech Brief 66–10124
1C48 NASA Tech Brief 66–10063
1C49 NASA Tech Brief 63–10170
1C50 NASA Tech Brief 66–10136
1C51 NASA Tech Brief 66–10064
1C52 NASA Tech Brief 66–10060

1D1 NASA Facts—Lesson Planning†
1D2 NASA Facts Volume III, No. 5
1D3 NASA Facts Volume II, No. 5 Supplement
1D4 NASA Facts Volume II, No. 8
1D5 NASA Facts Volume II, No. 15
1E1 "Spacequest 1965" (26 minutes). See list on page 161 for addresses to obtain films.
1F1 Photograph of mobile launcher
1F2 Photograph of Saturn V rocket
1F3 Photograph of Apollo modules
1F4 Photograph of command module
1F5 Photograph of Saturn V model
1F6 Photograph of Vehicle Assembly Building
1F7 Photograph of Complex 39 Launch pad
1F8 Photograph of launch gantry
1F9 Photograph of Merritt Island launch area
1F10 Photograph of Kennedy Space Center

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section 2
UNIT 2—METALS

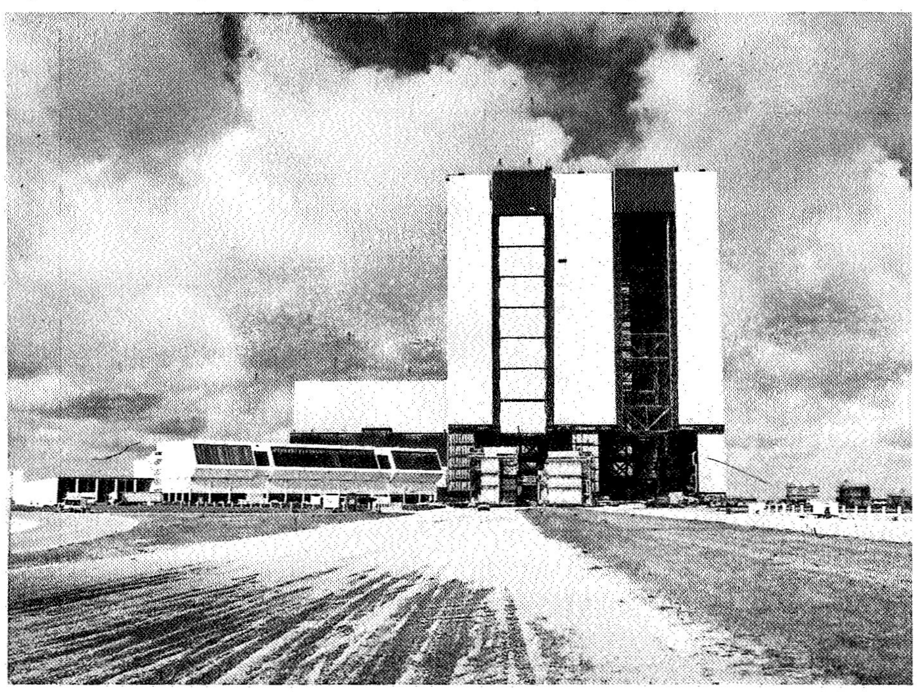
INTRODUCTION

One of the specialities recognized by NASA and listed as a separate employable occupation is *Aerospace Metals.* (2B8, p. 17)* This suggests that many space age technological requirements have been and will continue to be satisfied by conventional and innovative uses of metals.

The VAB (Vehicle Assembly Building), for example, is the world's largest building (52 stories high, covering 8 acres, and having 45 story high doors) and is where a totally new concept of space age assembly is emerging. It is essentially an all metal structure. (2D4) Fig. 2–1 and 2–2.

In addition to this building, many other ground support facilities—the mobile Apollo launch platform and its integrated crawler/transporter, the many gantrys and umbilical towers, the liquid fuel and purging gas storage tanks, the framework for the flame diverters, and the literally thousands of other items required for a successful launch—

Fig. 2–1. Photo of exterior of VAB showing size of building and "metal skin" surface.



**See page 9 for Reference Code.*

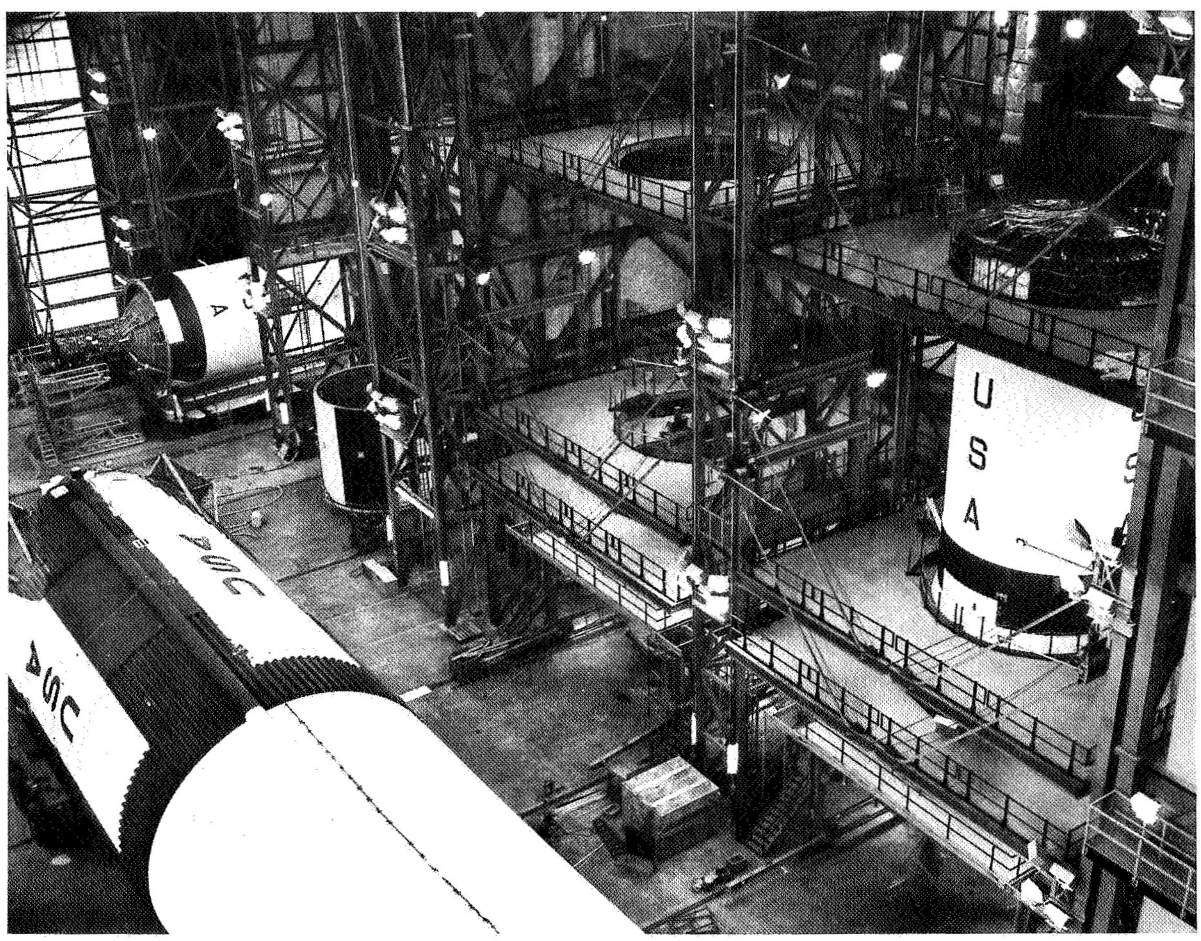
are for the most part fabricated from a variety of metal components. (2C14) Fig. 2–3 and 2–4.

Perhaps even more significant to the everyday observer, the actual spacecraft and its expendable launch vehicles are to a substantial degree of metal construction. A few representative statements quoted from the Gemini Spacecraft #8 Press Reference Book provide information supporting the fact that metals have the desirable properties which practically necessitate their extensive use. (2F1)

> Under the beryllium shingles are Thermoflex RF blankets held in place by a titanium mesh attached to the metal stringers. (2F1, p. 4)
>
> The adapter is a ring stiffened skin-stringer structure consisting of circumferential aluminum rings, extruded magnesium alloy stringers and a magnesium skin. (2F1, p. 8)
>
> Eighty-five percent of the cabin section, which includes equipment bay doors and hatches, is made of welded titanium assemblies. (2F1, p. 114)

Fig. 2–2. Photo of interior of VAB showing metal girder type contruction. (below)

Fig. 2–3. Photo of mobile Apollo launch platform with umbilical tower under construction. (at right)



Two hundred eighty-five inches of hand fusion welding are required to mate the thirteen titanium pieces of each hatch. (2F1, p. 115)

Thus, in an industry where function of a product is the overwhelming consideration, the basic properties of metals actually permit only limited use of other materials. In addition, the more demanding requirements of the future, together with the current state-of-the-art, are opening new frontiers for unique and more sophisticated applications for metals on our "way to the moon."

In the material that follows, a typical concept outline for metalwork instruction is detailed. Immediately to the right of each of these areas are listed *selected* appropriate space age applications that have implications useful for motivating and instructing the industrial arts student.

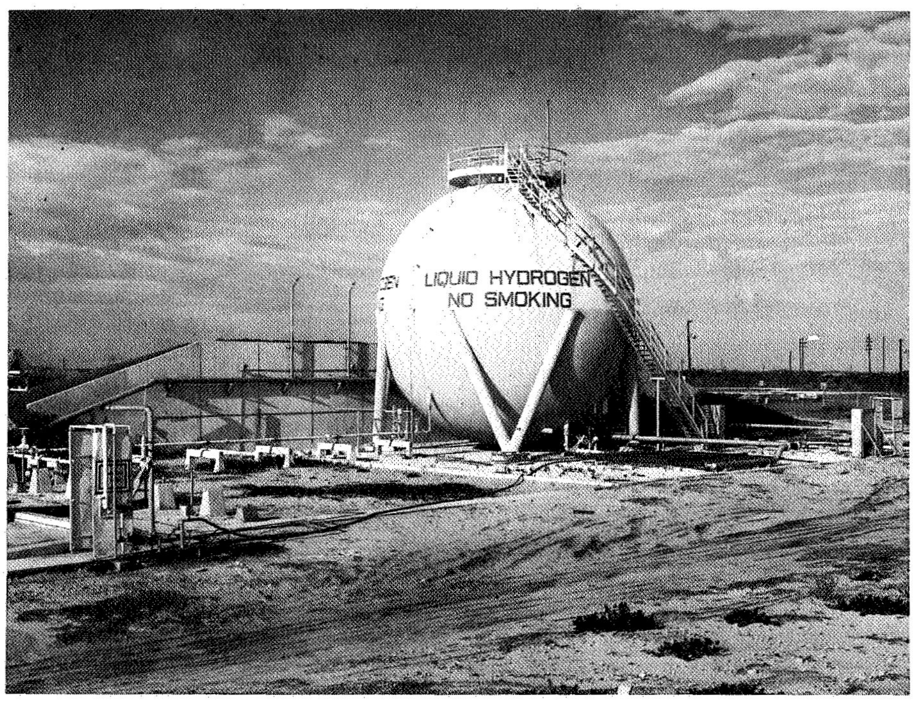


Fig. 2-4. Photo of liquid hydrogen storage tank.

LEARNING UNITS **AEROSPACE APPLICATIONS**

SAFETY

Safety procedures in the aerospace industry are extensive and universal. Examination of the following list will, however, indicate little variance from what is practiced in a well organized industrial arts laboratory. General safety items include:

1. Adequate physical plant environment temperature, ventilation (including dust removal), and lighting. (2F1, p. 120) (2B4, p. 45) (2D2, p. 7)
2. Guards on machines.
3. Safety lines or other devices around work areas.

LEARNING UNITS	AEROSPACE APPLICATIONS
	4. Proper clothing; eye protection, gloves, apron, "hard hats," etc. (2B4, p. 12) (2D8, p. 7) 5. Fire extinguishers of the proper type conveniently located. 6. Safe storage of dangerous materials. 7. Meticulous housekeeping. 8. Tools and equipment well maintained. 9. First aid facilities conveniently available.
PLANNING	Components for use in the NASA programs are manufactured by many companies in different locations throughout the United States. NASA facilities, such as the one at Cape Kennedy, do the final compatibility testing of all subsystems. This suggests that continuous and coordinated planning is most vital if ultimate success is to be assured when all of the parts are mated. (2D2, p. 7)
Layout	Space is at a premium and all parts must not only fit but be conveniently available for rapid replacement by substitution. (2D1, p. 2) (2F1, pp. 5–6)
Measurement	Most aerospace parts are described in feet and inches. For example, the Apollo command module is described as being conical in shape, 11 feet high and 13 feet in diameter. (2D2, p. 4) Decimal measurements also find extensive use. As a typical example, the wings of satellite Pegasus are covered with panels of aluminum sheet .0015, .008, or .016 inch in thickness. (2D8, p. 3)
Tolerance and Allowance	The extremes in environmental temperature encountered by a spacecraft, together with wide variations in the temperature of liquid fuels and resulting combustion, impose severe restrictions on dimensions used in fabrication. As an illustration, the "shingle" mounting holes on Project Mercury, of necessity, must be large enough to allow for expansion and contraction without buckling. On the other hand, some systems are kept in a controlled environment, and a very small amount of tolerance and allowance is permitted. (2F1, p. 7) The huge mobile Apollo portable launch platform must be level to within one-tenth of a degree of horizontal. (2D2, p. 9)
METALLURGY	Weight (optimum strength to weight), temperature (tremendous range), and manufacturing characteristics (fabrication and assembly) are items that are of continuous concern in space age metallurgy. (2A4, p. 28) (2F1, pp. 1, 4, 7, 8, 9, 64, and 113–124) In NASA publications listing preferred college majors, Metallurgy and Metallurgical Engineering are both listed. (2B8, p. 26) The materials engineer at Pratt and Whitney Aircraft is fundamentally a metallurgist. Metals development programs aimed at great strength at elevated temperatures, superior resistance to oxidation and corrosion, higher strength-to-weight ratios, or lower content of critical

elements are typical of the continuous and intensive materials exploration. (2F3)

It is difficult to "isolate" metals as they are usually tailored to specific applications by alloying. (2B4, p. 33)

Materials (Ferrous)

Steel is used extensively in the ground support activities. In the Apollo project, for example, there is the VAB, the mobile launcher, the mobile service structure, the supporting structure for the flame diverter, portions of the liquid fuel and purging gas storage tanks, the huge tracked crawler/transporter, and many others. (2F2)

Steel is also used in the Apollo launched vehicle; the LM (Lunar Module), for example, has "four jointed steel-truss legs." (2D9, p. 4) Fig. 2-5.

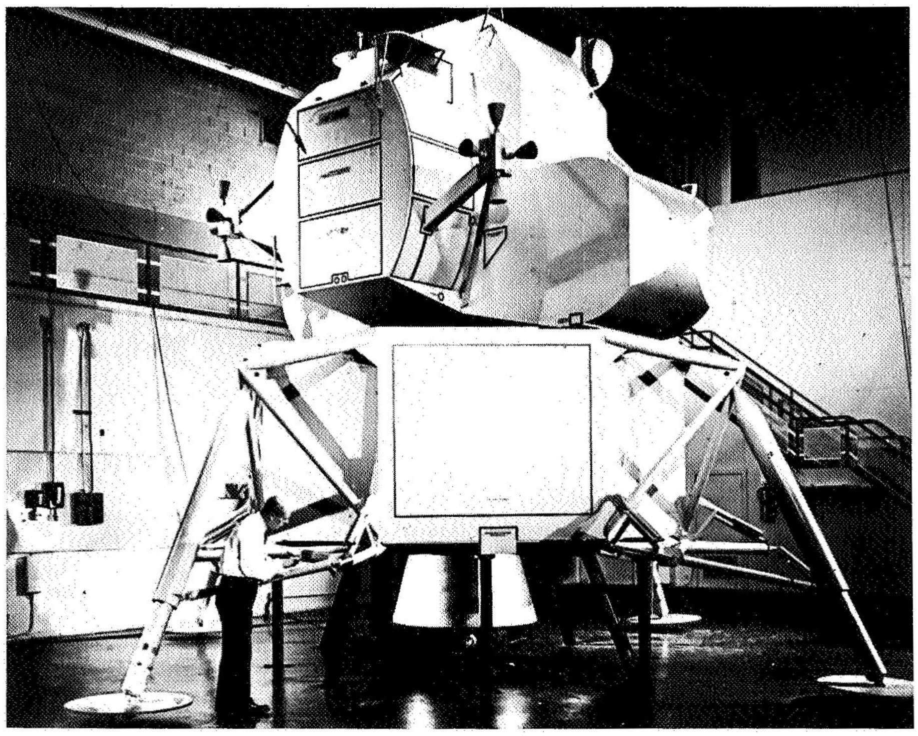


Fig. 2-5. Photo of LM mockup showing construction.

(Non-Ferrous)

The micrometeoroid satellites contain pressurized beryllium copper cylinders, copper wire (2 and 3 thousandths inch thick) grids, aluminum sheet (.0015, .008, and .016 inch) panels to record the number encountered. (2D5, pp. 2-3)

The major structural material for the Apollo service module and the LM is aluminum. (2D2, p. 5)

The inner shell of the Apollo spacecraft is made of aluminum honeycomb bonded between sheets of aluminum alloy. (2D2, p. 4)

The world's first passive communications satellite, Echo, is almost 100 feet in diameter and has an aluminum reflective surface. (2F9, p. 2)

"New" metals, such as titanium, are used in certain critical areas, such as the joining straps between the adapter and the re-entry module of the Gemini. (2F1, p. 8)

(Alloys)

Personnel from the NASA Lewis Research Center suggest that the aerospace age is the "age of tailored materials" since no single material can serve all of the many technological applications required. In addition, metallurgists are designing improved fabricating characteristics into alloys. (2B4, p. 33)

Solder, an alloy of tin and lead, used in NASA work must conform to Federal Specifications QQ–S–571, Type RA, composition SN60 or SN63. (2B1, p. 11) (2B7, p. 4–11)

The shingles on the surface of the Gemini re-entry module are alloyed of several metals—53% nickel, 19% chromium, 11% cobalt, 9.75% molybdenum, 3.15% titanium, 1.6% aluminum, .09% carbon, .005% boron, and less than 2.75% iron—to provide aerodynamic and heat protection in addition to holding insulation in place. (2F1, p. 7)

Stainless steel sheets surround a stainless steel honeycomb on the outer shell of the Apollo command module. (2D2, p. 4)

Work at Pratt and Whitney Aircraft emphasizes a materials spectrum which ranges from stainless steel and iron-base super alloys, to magnesium, aluminum, titanium, and all varieties of advanced high temperature nickel and cobalt base super alloys. (2F3)

Testing

Every item in the Apollo spacecraft—beginning with bolts and nuts—is subjected to rigorous inspections and tests. Each component is tested far beyond the required safety level and, in many cases, to the point of breakdown to determine performance margins. The above statements are typical of the importance attached to the necessity for adequate testing. (2D2, p. 6) (2E1)

In some instances procedures have been developed to shorten the test time and/or specimen size and still obtain predicted results. This procedure will become increasingly important as time spent in space becomes longer and as size requirements become larger. (2B4, pp. 38, 52)

A 15-ton stainless steel vacuum chamber at North America's aviation plant in Downey, California, will permit tests in a simulated space environment. (2D2, p. 7)

(Destructive)

Shear test samples are made on spot, stitch, and seam welds. (2F1, p. 117)

Destructive inspection of welds is made by either a pull-test or metallurgical test. This type of testing is expensive, time consuming, and it destroys the product; nevertheless, it is the only method available for obtaining certain data about the parameters of a weld. Since the method is destructive, it must be used only on a sampling basis. (2B2, pp. 34–39)

LEARNING UNITS	AEROSPACE APPLICATIONS
(Non-Destructive)	All welds get a visual (size and shape) inspection. A penetrant inspection is done on non-magnetic materials. One hundred percent radiographic inspection is done with few exceptions. Inspection fixtures were designed to check tolerances at various stages of assembly. (2F1, p. 117) (2B2, pp. 26–34) Sampling inspection procedures are used for standard nuts, bolts, and raw materials. (2F1, p. 120)
Properties (Strength (Hardness) (Brittleness) (Ductility) (Fatigue) (Malleability) (Elasticity)	The ideal material on the basis of performance requirements seems to have the characteristics of being difficult in either forming, machining, or joining. (2B4, p. 6) If there is any ductility at all in tungsten or molybdenum before it is welded, it is gone after welding. (2B4, p. 7) Beryllium can be improved in ductility by alloying with other metals. (2B4, p. 45) A unique solution to reduce shear pin fatigue and still provide overload protection is described in NASA Tech Brief 66–10077. (2C11) Certain metals are called refractory metals because of their high melting point—above 3300 degrees Fahrenheit. (2B4, p. 7)
Heat Treating (Hardening) (Tempering) (Annealing) (Sintering) (Normalizing) (Case Hardening)	Materials may be heated either during or after forming to improve desirable characteristics. A simple example of this type of heat treatment is illustrated in NASA Tech Brief 66–10009. (2C2) Age forming is actually a combination of heat treating and draw forming. The product is overformed and heated. When the pressure is released, it opens up; retention of part radius varies with the metal being formed. (2F4, p. 77) Fig. 2–6. In some instances it is possible to restore the strength and/or ductility of the metal, which was decreased during welding, by an appropriate heat treatment process. (2B4, p. 22)
FORMING Hand (Sawing) (Filing) (Drilling) (Tapping) (Threading) (Cutting)	Examination of NASA Tech Briefs together with visual observations suggests that there is considerable use made of hand forming tools. Much of the "hardware" is of a prototype "few of a kind" fabrication not lending itself to mass-production techniques. (2A2, p. 110) (2A1, p. 26) A simple pipe cutting tool for use in restricted space is covered by U.S. Patent No. 3, 136, 057 waived under the provisions of the National Aeronautics and Space Act. (2C15) NASA Tech Brief 66–10123 denotes a solution to the problem of drilling a hole to the correct depth with a hand drill. (2C16) Fig. 2–7. A specially designed tool kit with 16 hand tools to be used by the

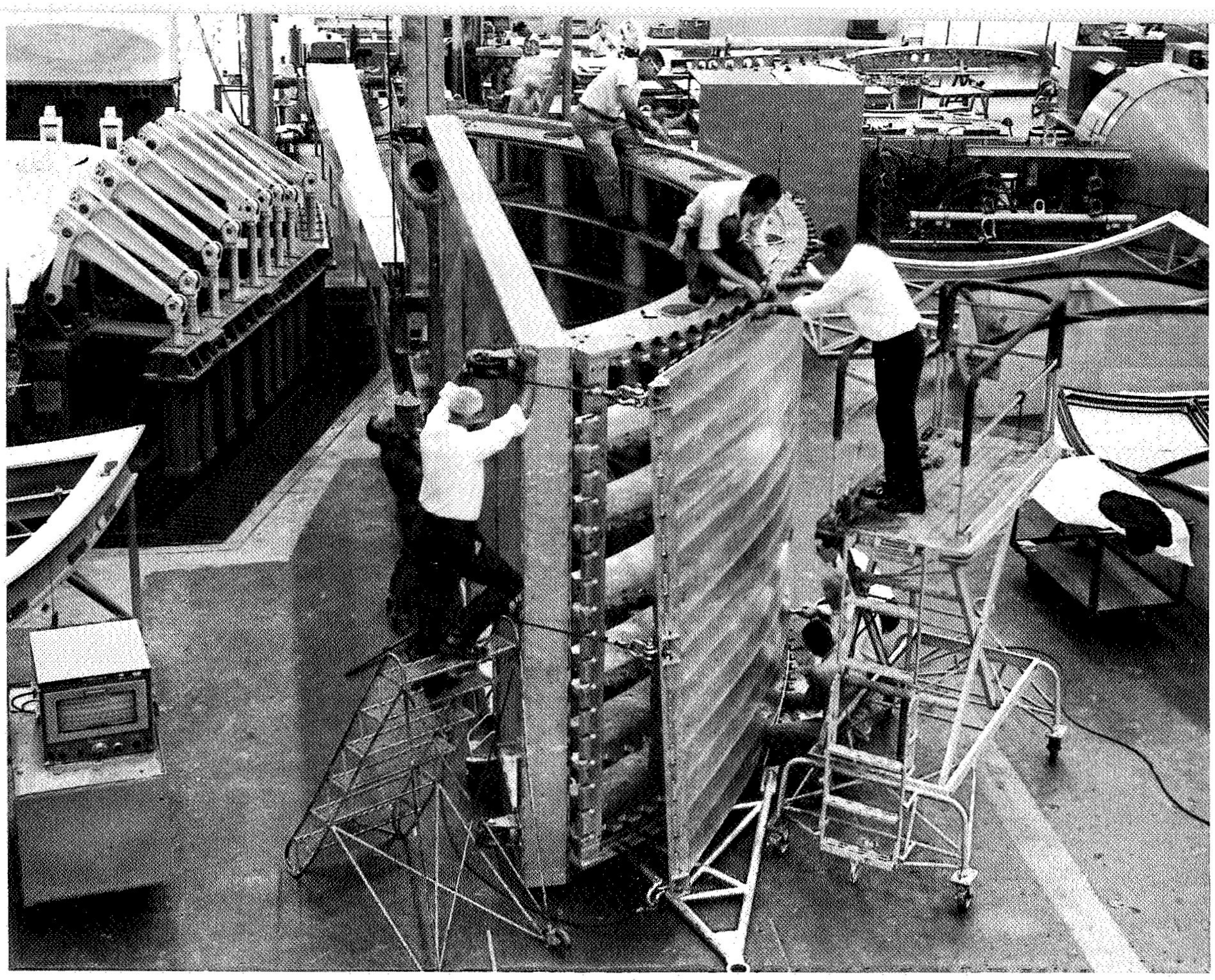


Fig. 2–6. Photo: Preparing a Saturn S–1C sulptured aluminum skin for age forming.

LEARNING UNITS **AEROSPACE APPLICATIONS**

exploring Apollo astronaut has been delivered to NASA. The main item is a battery powered drill. (2F7, p. 39)

An innovation for a chart carrying case that doubles as an easel for aerospace lecturers is strikingly similar to a typical industrial arts metalworking project. (2C18) Fig. 2–8.

Machining (machine shop)
(Drill Press)
(Lathe)
(Shaper)
(Miller)
(Grinder)
(Saw)
(Jig Borer)
(Electric-Discharge)
(Electrochemical)
(Chemical)

NASA subcontractors and NASA experimental and maintenance laboratories all make extensive use of customary machine shop equipment. A part must often be made that has never been made before. Various jigs and fixtures facilitate even limited quantity production and help maintain required tolerances for precise equipment (2B4, p. 6) (2B3, pp. 19–25) Fig. 2–9.

The "old reliable" processes of machining are being adapted to handle many of the newer requirements, but the high energy rate forming methods are being developed and refined and will probably play an ever increasing role in the future. (2B4, pp. 8–20)

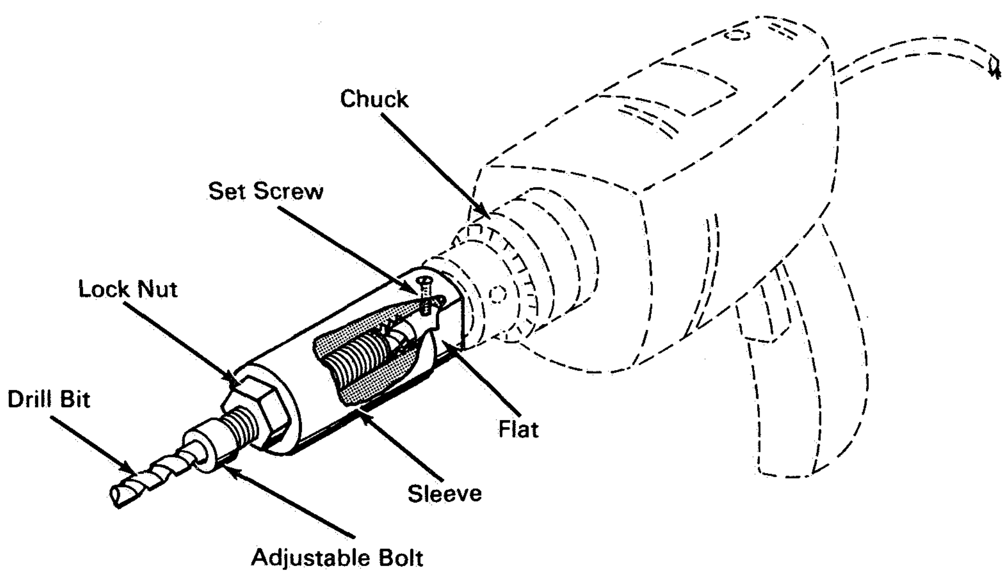
Even though sizes are sometimes very large, procedures are very similar to industrial arts. For example, an article in a recent magazine describes the machining of Saturn transition rings as follows: "We rough face the inside leg to a height of 26⅛ inches and rough bore the

March 1966 Brief 66-10123

NASA TECH BRIEF

NASA Tech Briefs are issued to summarize specific innovations derived from the U. S. space program and to encourage their commercial application. Copies are available to the public from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Hand Drill Adapter Limits Holes to Desired Depth



The problem:
To provide a device that will accurately limit the depth of a hole bored with a hand drill.

The solution:
An adjustable adapter than can be fastened to the shank of a drill bit.

How it's done:
A cylindrical sleeve is secured to the chucked bit by means of a set screw tightened against the shank of the bit. A hollow, adjustable bolt having a squared-off shoulder surrounds the drill bit, and is screwed into the end of the sleeve. The bolt may be adjusted to expose a selected length of the bit, and secured by tightening a locknut against the sleeve. The shoulder of the bolt limits the penetration of the bit into the material being drilled. Flats on the cylindrical sleeve permit the use of two wrenches for tightening and loosening the locknut.

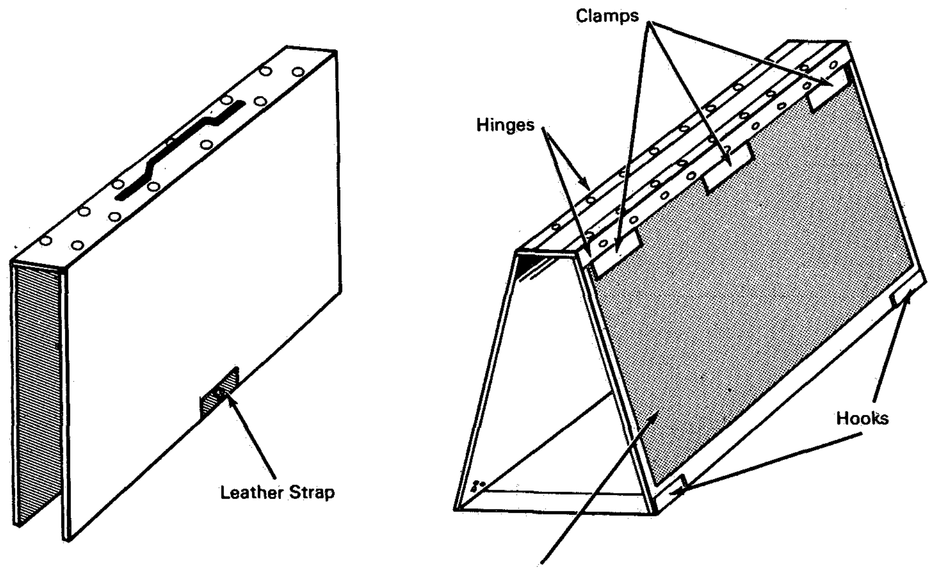
Fig. 2–7. Tech Brief showing a simple solution to the problem encountered frequently in both industrial arts and space age metallurgy.

April 1966 Brief 66-10135

NASA TECH BRIEF

NASA Tech Briefs are issued to summarize specific innovations derived from the U. S. space program and to encourage their commercial application. Copies are available to the public from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

Chart Case Opens to Form Briefing Easel



The problem:

To provide a chart carrying case that will also serve as a briefing easel.

The solution:

An aluminum carrying case that protects charts during transit and opens to form a rigid easel for easy presentation of the charts on display.

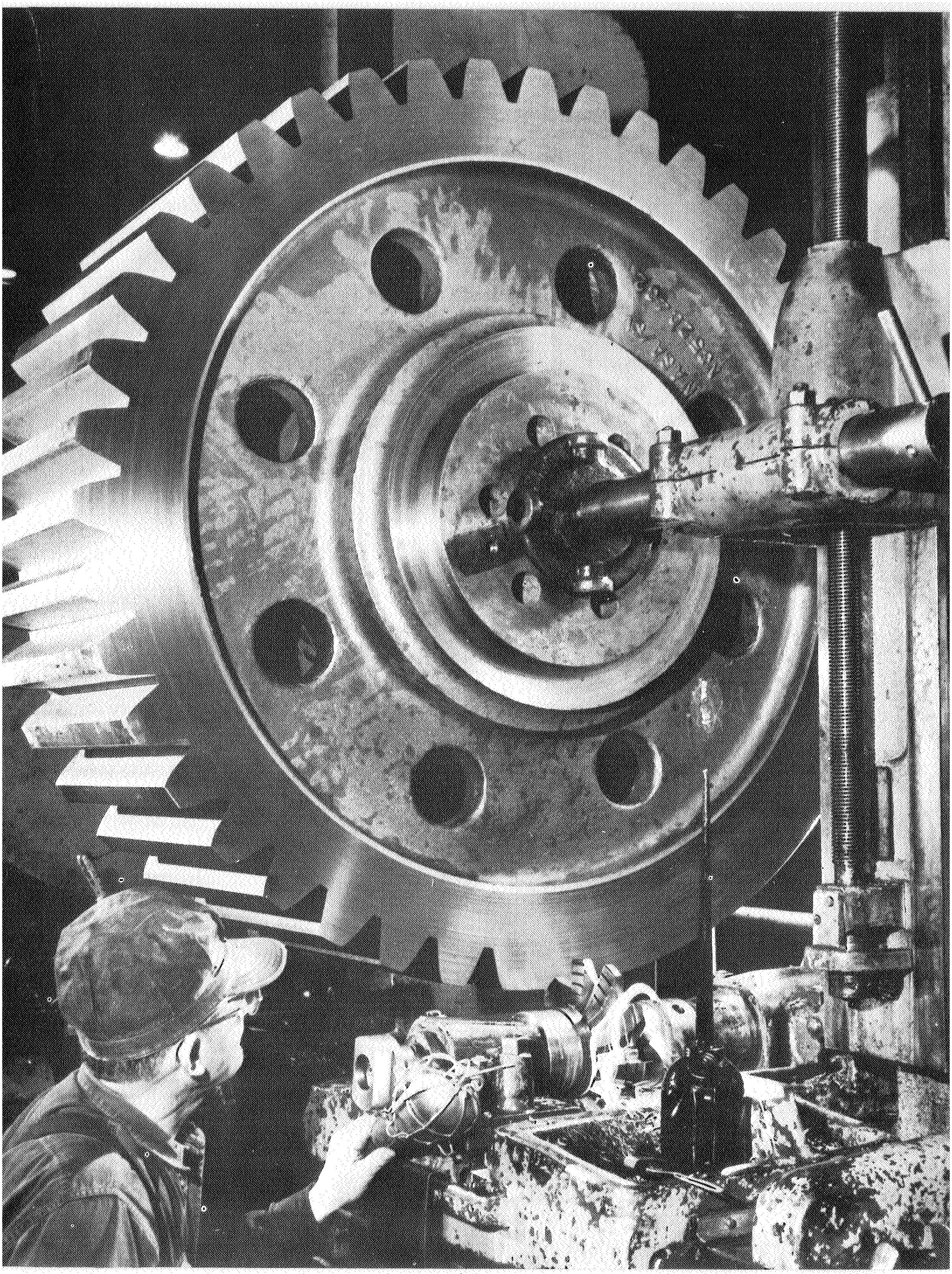
How it's done:

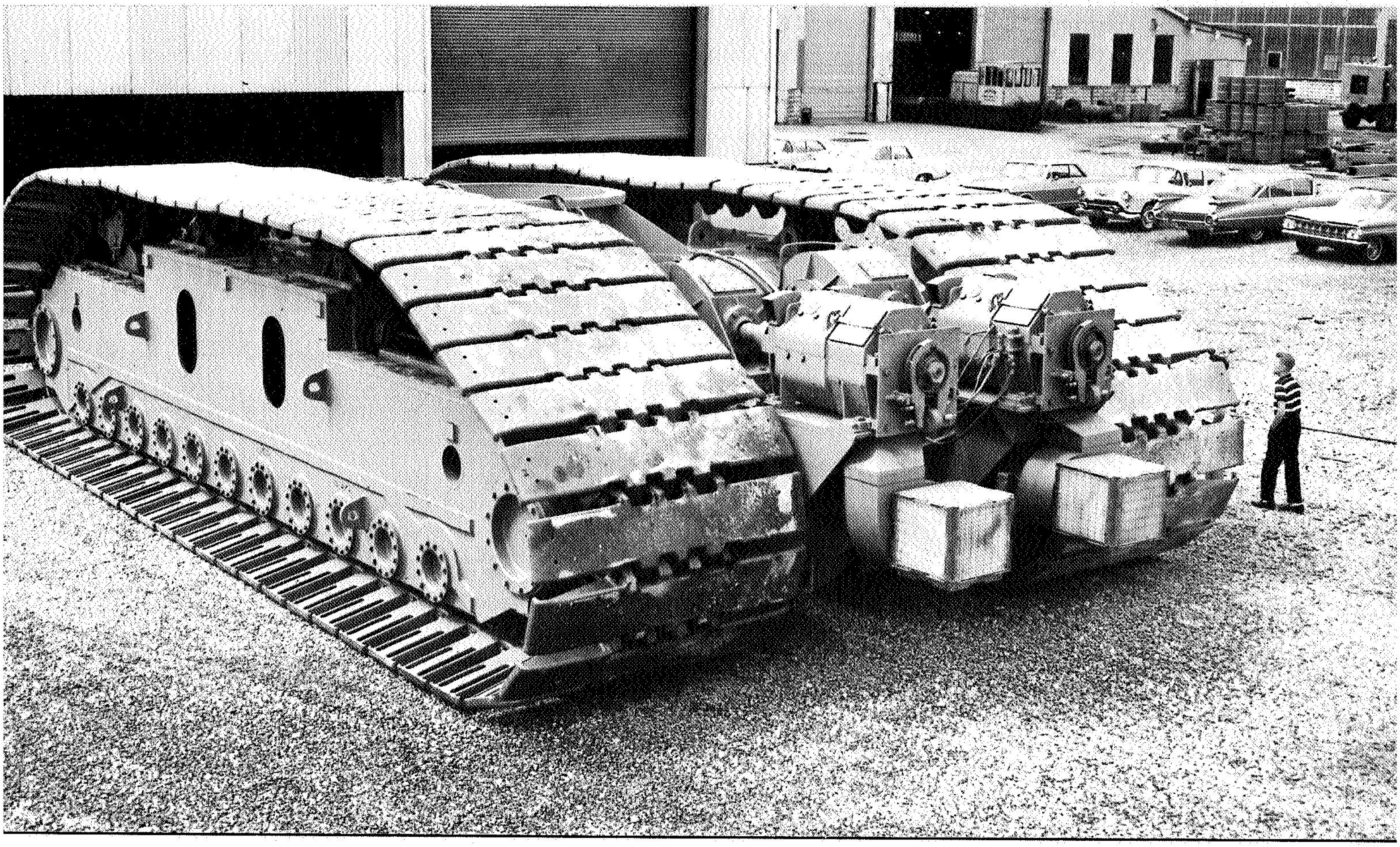
Two aluminum sheets hinged to an aluminum strip form a book-shaped assembly. Three triclip looseleaf clamps mounted inside the structure hold the charts, and a drawer pull fastened to the outside face of the strip provides a carrying handle. A leather strap fastened across the open end of the device locks it shut. For display, the strap may be unfastened and the two faces rotated 160° each, locking at the open end by two hinged hooks to form an inverted V-shaped easel. The charts are thus exposed for display and may be rearranged easily using the quick-action clamps.

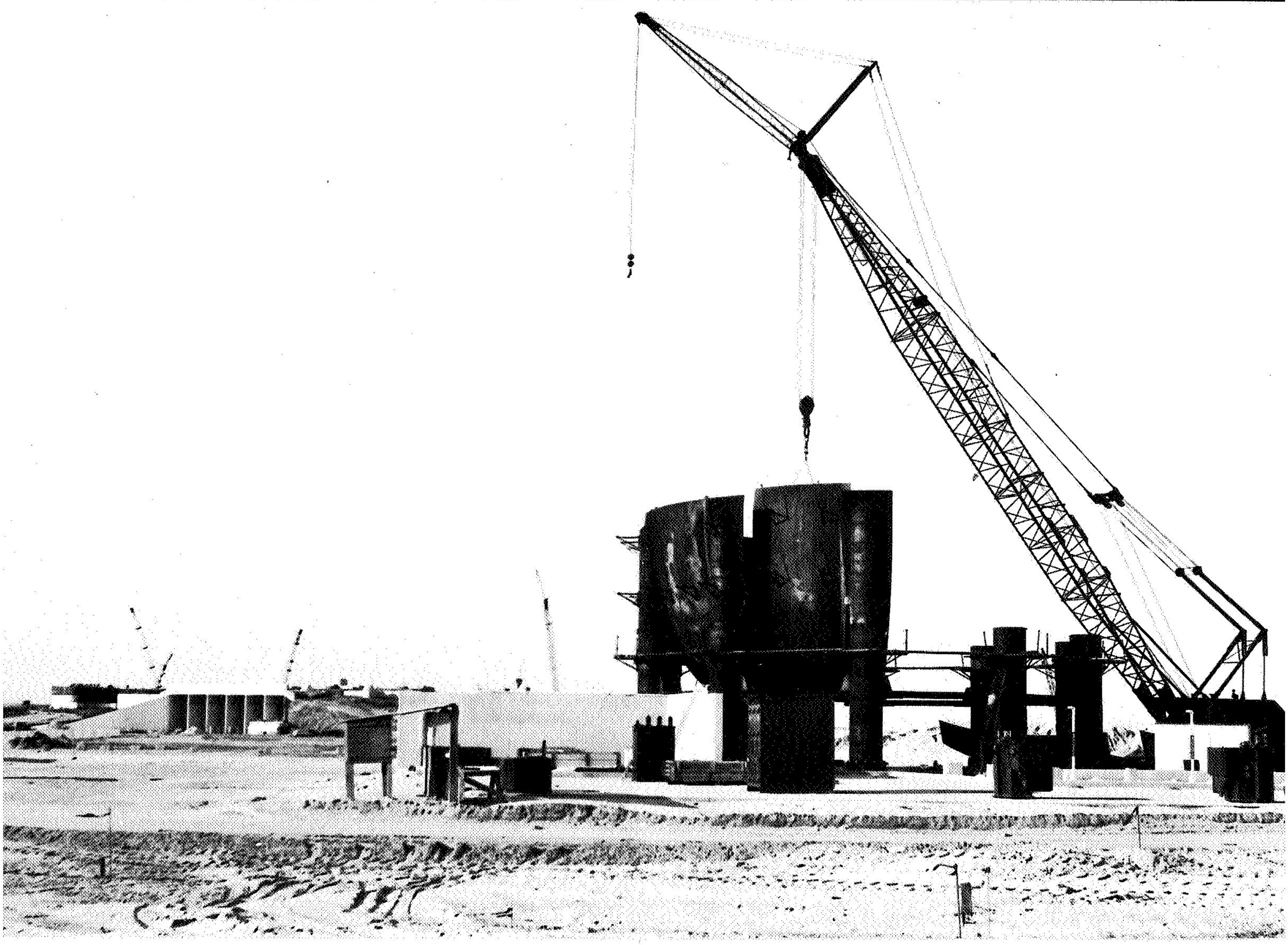
Fig. 2–8. Tech Brief showing a type of project that could have been fabricated by an industrial arts student.

LEARNING UNITS	AEROSPACE APPLICATIONS
	ring to 387¼ inches diameter. Finally, we space the plate type drill jig around the perimeter of the ring." (2F6, p. 74)
Forging	The Gemini spacecraft and the Titan II launch vehicle are mated by using a forged aluminum alloy ring. (2F1, p. 9) The crawler/transporter contains 270 tons of forged steel parts. Included are 176 forged steel rollers weighing 2010 pounds each and 8 forged steel guide tubes weighing 23,470 pounds each. (2F9, p. 283) Fig. 2–10.
Casting (Shell) (Sand) (Die) (Precision) (Permanent Mold) (Powdered Metal)	Wind tunnel models are fabricated by precision casting. (2B9, p. 2)
Spinning	An outgrowth of skilled-craft conventional spinning has led to power shear spinning. The huge 105 inch diameter Saturn I bulkheads are fabricated in this manner from 5/6 inch aluminum plate. (2B5, pp. 5–9)
Press (draw)	Variations of conventional draw forming with matching male and female dies and expected high production are common in the spacecraft industries. Rubber forming, drop hammer forming and stretch forming reduce tooling costs and are acceptable for limited production. (2B5, pp. 1–5) A simple forming tool to increase the quality of tubing flares is illustrated in Tech Brief 66–10001. (2C1)
Punch	The many electronic items, such as radio receivers, used in telemetry activities are for the most part fabricated on sheet metal chassis. The numerous cutouts are fabricated by means of punch and die operation.
Thin Gauge (sheet and art metal) (Beading) (Burring) (Crimping) (Folding) (Shearing) (Roll Forming) (Seaming)	Since "flight weight" is such an important consideration in the spacecraft and launch vehicle, thin gauge metals are used extensively. Twenty-five different forming techniques are currently being used by the aerospace industry. (2B5, p. 1) The outer sheet of the Gemini spacecraft is beaded for stiffness. (2F1, p. 5) An adapter for a regular machinist's vice permits metal tubing to be held securely and yet without marring for various operations such as burring. (2C7) A new method for forming thin walled seamless tubing for the LOX (liquid oxygen) lines of the Saturn V has been developed. This replaces

Fig. 2–9. Photo of a large gear for the crawler/transporter being milled in "industrial arts fashion."







LEARNING UNITS	AEROSPACE APPLICATIONS
	the rolled and seam welded technique previously used. (2B5, pp. 48–51)
High Energy Rate (Explosive) (Electrospark) (Magnetic) Metal Deposition (Metallizing) (Thermospray) (Plasma Flame)	Most explosive forming results in one piece hemispherical components that would be difficult, if not impossible, to fabricate in any other manner. (2A6, p. 43) (2B5, pp. 28–42) (2C4) (2C5) Certain required shapes can best be fabricated from tungsten and molybdenum by using metal spraying. (2B4, p. 13) Electroforming will also produce shapes that are practically impossible to fabricate by other methods. (2B4, p. 14)
JOINING Welding (Gas) (Arc) (Inert Gas) (Resistance) (Electron Beam) (Sonic)	A master chart of welding processes categorizes the many techniques available. Further information is available in the NASA annotated bibliography on welding methods. (2B2, p. 4) (2B6) Two hundred eighty-five inches of handfusion welding are required to mate the thirteen titanium pieces of each Gemini hatch. (2F1, p. 115) Oxidation caused by the high temperature of welding is eliminated by use of a specialized tool for tube welding. (2C13) A requirement that the serpentine tubing be welded to a flat surface without obstructions caused by weld nuggets required the use of a high melting point and porous material (aluminum oxide) for a filler. (2C17) Special weld joint configurations are needed on pipe used to transfer cryogenic fluids. A simple jig plus a standard router (as used in industrial arts) permits field preparation. (2C19) Frequently, current supplied to the welding arc needs to be accurately and continuously controlled. A fingertip type of control is most desirable since its use in confined areas and the degree of precision is very good. (2C12) The liquid fuel storage tanks are fabricated from sections that are arc welded together forming a spherical shape. Fig. 2–11. Protection is provided for the weld metal by an inert gas in a welding chamber; this is especially important when working with such space age metals as tantalum and columbium. (2B4, p. 22) Production welding of the 33-foot diameter, 138-foot long cylindrical assembly for the Saturn S–1C booster rockets is performed with TIG equipment and procedures. (2F5, p. 112)

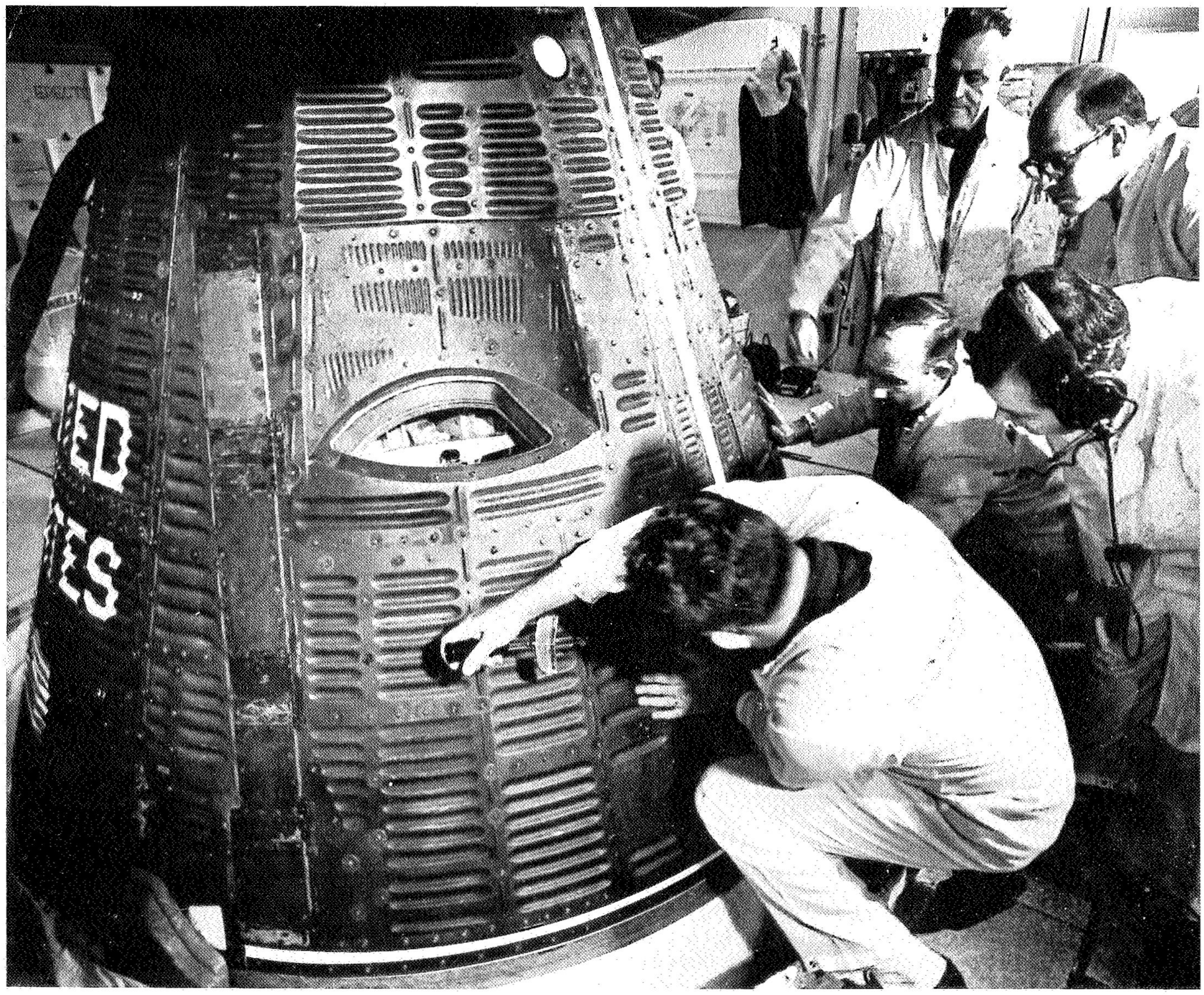
Fig. 2–10. Photo of the crawler tracks showing much evidence that forgings and castings are used. (2A5, p. 364)

Fig. 2–11. Photo of fabricating the liquid hydrogen storage tank at Pad 39A—"The Gateway to the Moon."

LEARNING UNITS	AEROSPACE APPLICATIONS
	Eighty-five percent of the pressurized Gemini cabin is made of welded titanium assemblies. (2F8, p. 97)
	A recent invention increases the stability of a hand held spot welding gun and also improves the quality of the spot weld. (2C10)
	More than 20 types of similar metals and 31 different combinations of dissimilar metals have been successfully explosive welded. Tensile tests of all of these welds have proved that they are stronger than the basic metal. And, significantly, no molecular change had occurred in the metals as a result of the weld. (2F3, p. 18)
Brazing	The many stainless steel tubes that are fastened to the rocket injector face and used for cooling are attached by means of brazing. (2B4, p. 29) Sides of the Apollo command module outer shell are constructed primarily of stainless steel honeycomb brazed between stainless steel sheets as thin as eight thousandths of an inch. (2D2, p. 4)
Soldering	The failure of only one electrical connection can result in system abort and mission failure. This possibility necessitates a thoroughly disciplined approach to hand soldering. (2B7, p. i)
Bolting, Riveting, Metal Screws, etc.	The Gemini spacecraft and Titan II launch vehicle are fastened together with 20 bolts. (2F1, p. 9) Fig. 2–12.
	Many of the ground support structures are riveted together; namely, the gantrys, service towers, and umbilical towers. (2A3, p. 116)
	Mechanical fasteners lock the outer shells of the Apollo spacecraft securely and rigidly together. (2F1, p. 4)
	Every item in the Apollo spacecraft, beginning with nuts and bolts, is subjected to rigorous inspection and tests. (2F1, p. 6)
	Three rather specialized innovations for driving bolts and nuts are described in NASA Tech Briefs. All of these tool adaptions are illustrative of devices that would also solve assembly problems in industrial arts and other industries. (2C3) (2C6) (2C9)
Bonding	An extremely simple and versatile clamp permitting specific pressure for bonding was developed for NASA and described in a Tech Brief. This clamp would be equally useful in industrial arts. (2C8)
FINISHING Polishing Plating	Corrosion is a very difficult problem to solve due to the extremes of temperature encountered by the spacecraft and launch vehicles and the salt air atmosphere so prevalent at Cape Kennedy.
Anodizing	Air bearings for space vehicles guidance devices have necessitated using hard anodized aluminum laps with a surface hardness equal to that of a sapphire. (2B3, pp. 3–8)
	The 25.190 $\pm$ 0.015 inches OD by 44 feet long seamless Saturn tunnel is anodized for protection against corrosion. (2B5, pp. 50–51)

LEARNING UNITS	AEROSPACE APPLICATIONS
Coating	The dark color of the Gemini re-entry module is characteristic of the coatings used to provide heat protection. The white exterior of the adapter module provides for maximum release of heat brought to the metal surface by spacecraft coolant lines. (2F1, p. 1) According to NASA, organic coatings of clamps and brackets by the Fluidized Bed Technique are solving many corrosion problems. (2F11, pp. 6–7)

Fig. 2–12. Photo of torquing the bolts that hold the Gemini spacecraft hatch closed.



SAMPLE TEACHING UNIT

METALS

PREPARATION OF A SOLDERING IRON

Problem

The lack of a relatively simple skill, soldering, has caused many delays, and in at least one instance, a failure of a space launch. It is conservatively estimated by NASA that once a launch is initiated each delay costs thousands of dollars.

Information

It has been determined that one of the very important steps in soldering is the proper preparation and maintenance of the soldering iron.

Activity

Investigate the following items concerning the soldering iron:

1. Is the body of the tip free of oxide, fully inserted into the heating element, and securely fastened to the iron?
2. Does the soldering end of the tip have a bright and continuous tinned surface to insure proper heat transfer and avoid transfer of impurities to the solder connections?

If the tip is not in a completely satisfactory condition as described above, clean the body and dress the tip, *while cold,* with a single cut file. After filing, the iron should be heated, and when the tip reaches the *lowest* temperature required to melt solder, solder shall be applied to the tip. The hot tinned tip shall then be cleaned by wiping it lightly on a wet, fine-texture natural or synthetic sponge.

Sources of Information

2B1, p. 21
2B7, pp. 5–11

Possible Related Experimentation

Determine the melting point of tin, lead, and the two NASA accepted alloys compounded from these two metals. (Commonly accepted percentages are 60–40 and 63–37.)

REFERENCE MATERIALS

METALS

(Film List—See Appendix II, page 161)

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2A2 Feirer, John L. General Metals. New York: McGraw-Hill Book Co., 1967.

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2B1 NASA SP-5002 Reliable Electrical Connections, Office of Technical Services, Department of Commerce, Washington, D.C. 20230. $.70

2B2 NASA SP-5011 Welding for Electronic Assemblies, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.40

2B3 NASA SP-5013 Precision Tooling Techniques, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.25

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2B6 NASA SP-5024 Bibliography on Welding Methods, Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151. $1.00

2B7 NASA NPC 200-4 Quality Requirements for Hand Soldering of Electrical Connections, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.45

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2C1 *NASA Tech Brief 66-10001
2C2 NASA Tech Brief 66-10009
2C3 NASA Tech Brief 66-10011
2C4 NASA Tech Brief 66-10014
2C5 NASA Tech Brief 66-10029
2C6 NASA Tech Brief 66-10054
2C7 NASA Tech Brief 66-10056
2C8 NASA Tech Brief 66-10059
2C9 NASA Tech Brief 66-10077
2C10 NASA Tech Brief 66-10092
2C11 NASA Tech Brief 66-10093
2C12 NASA Tech Brief 66-10097
2C13 NASA Tech Brief 66-10102
2C14 NASA Tech Brief 66-10123
2C15 NASA Tech Brief 66-10125
2C16 NASA Tech Brief 66-10135
2C17 NASA Tech Brief 66-10145

2D1 NASA Fact Sheet #291
2D2 NASA Fact Sheet #292
2D3 NASA Fact Sheet—Crawler/Transporter
2D4 NASA Fact Sheet—Vehicle Assembly Building (VAB)
2D5 NASA Facts Volume II, No. 4†

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REFERENCE MATERIALS

METALS

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2D7 NASA Facts Volume II, No. 8
2D8 NASA Facts Volume II, No. 15
2D9 NASA Facts Volume III, No. 1
2D10 NASA Facts Volume III, No. 4
2E1 "Test for Success" (28 minutes), Goddard Space Flight Center, Greenbelt, Maryland
2F1 Gemini Spacecraft #8 Press Reference Book, McDonnell Aircraft Corporation, St. Louis, Missouri
2F2 Gateway to the Moon, Kennedy Space Center, Cocoa Beach, Florida
2F3 Applied Research for Rocket Propulsion, Pratt and Whitney Aircraft, West Palm Beach, Florida
2F4 American Machinist Magazine, September 14, 1964
2F5 American Machinist Magazine, June 7, 1965
2F6 American Machinist Magazine, July 5, 1965
2F7 American Machinist Magazine, March 14, 1966
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section 2

UNIT 3—ELECTRICITY-ELECTRONICS

INTRODUCTION

The area of Electricity-Electronics as applied to aerospace technology is almost limitless in its scope. It is said that electronics is the heart of the program, and all phases of electricity provide the means to accomplish the many production tasks required in the manufacturing and assembly processes. Fig. 3–1.

Illustrations of this correlation can be found in the power required for welding, motor-generator applications, communications, transportation, etc. In fact, in every phase of every aerospace industry, every production line procedure or every operation involved can be found Electricity-Electronics as the basic tool to integrate the over-all program.

One who decides to pursue a career in this particular area has an almost unlimited horizon upon which he can build his future. It is suggested that anyone interested in further documentation refer to NASA Twentieth Century Explorer, A Guide to Careers in Aero-space Technology. (Available from NASA Headquarters, Code FAD–1, Washington, D.C. 20546.)

LEARNING UNITS

BASIC CONCEPTS OF ELECTRICITY
Atomic Theory and Structure of Matter
(Nuclear Structure)
(Comparison of Elements)
(Special Materials)

Static and Dynamic Electricity
(Generation of a Static Charge)
Momentary and Sustained Flow)
(Electrostatic Series of Materials)

AEROSPACE APPLICATIONS

Ion engines and fuel cells are extensively used for power sources in space vehicles. Hydrogen, oxygen, nitrogen, and helium are a few illustrations of the basic elements used for fueling space vehicle engines. (3A2,* pp. 11–19)

Space vehicles use principle of planetary rotation in orbits about the earth with gravity being the nucleus or forces of attraction which is similar to the structure of the atom. (3B1, pp. 14–19)

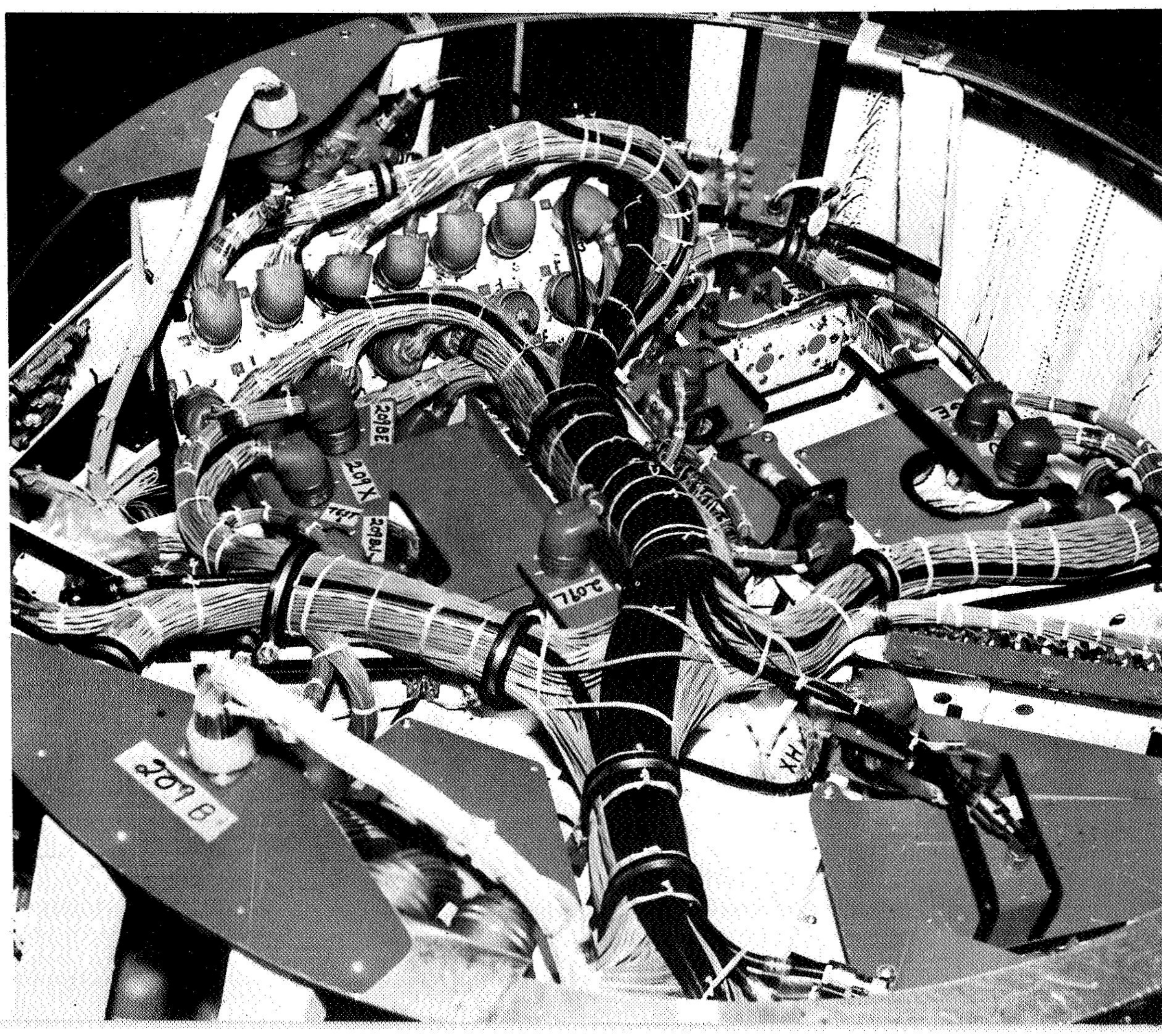
Static charges build up on the surfaces of the spacecraft which presents a hazard in docking maneuvers. Extensive shielding and grounding are required to eliminate or neutralize these charges. (3B1, pp. 37–42)

Re-entry of capsule causes shock waves to be set up creating an ionized plasma. This phenomena creates interference with communication equipment during period of re-entry. Fig. 3–2.

**See page 9 for Reference Code.*

LEARNING UNITS	AEROSPACE APPLICATIONS
(Explosive Forming) (Electric Discharge Machining)	Demonstrate fluid injection principle on electrostatically charged bodies. (3B8, pp. 6–32)
Components and Symbols	Space industry uses currently accepted symbols with a few noted or otherwise indicated exceptions. Terminology is major differential. (3B1, pp. 63–72) Approximately 98% of all components used are of solid state type. There is a concerted effort made toward minaturization. (3B5) Quality control and reliability are major considerations for manufacturing and assembling of components and connectors. Develop a spacecraft circuit board using typical components. Develop standards of quality to measure reliability of connections.
Sources of Electrical Energy (Creating Electromotive Forces) Cells and Their Structure)	Mechanical generators are used at launch sites to maintain a continuous flow of power. Chemical batteries are used for transportation vehicles and in the principles of the fuel cells for powering spacecraft equipment. Silver,

Fig. 3–1. Electronics gear is the heart of the space program.



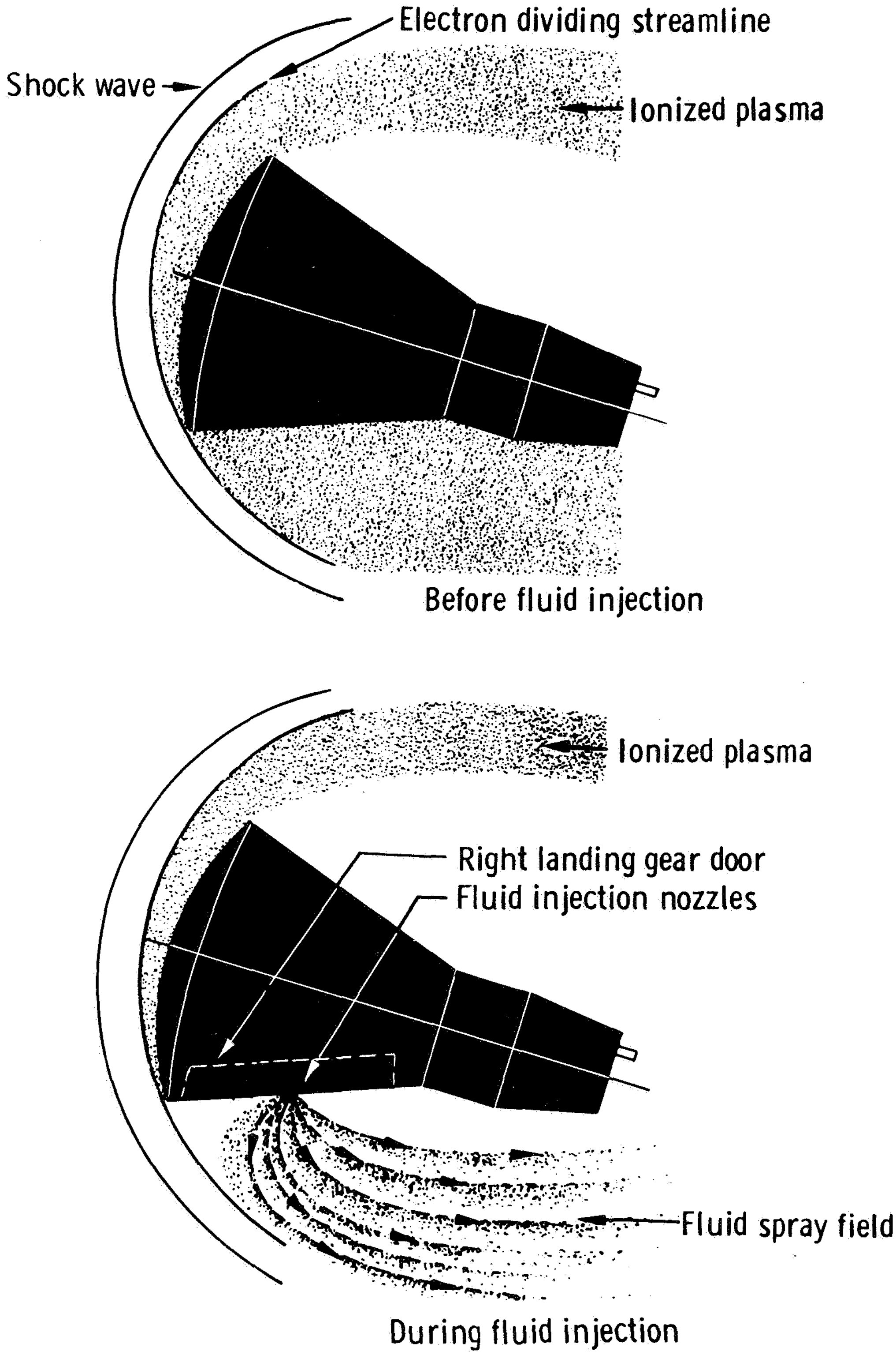


Fig. 3–2. Shock waves set up by Gemini capsule during re-entry. This interferes with communications.

LEARNING UNITS	AEROSPACE APPLICATIONS
(Electrical Power—Heat and Light)	zinc, and nickel cadmium cells are also extensively used in spacecraft. (3B8) Solar or light cells are used for the space capsule power source particularly where fuel supply problems are critical. Apollo program used this concept. (3B8) Heat or thermocouple cells are characteristically found in the sensors for measuring and warning devices. Wide temperature variations seriously affect electronic components. Therefore, extensive attention is paid to cryogenics, air-conditioning equipment, biochemical sensors, and other temperature regulating devices. (*Note:* See Heat Effects section.) Develop and/or demonstrate simple chemical, thermal, or solar cells. Show the effect of variations of temperature on cells or other components used to create electrical energy.
Circuit Analysis and Application (Ohms Law) (Series Circuits) (Parallel Circuits) (Combination Circuits)	Entire space program is based upon proper functioning of electrical circuits. Life of the space traveler is dependent upon accuracy and reliability. (3B8; pp. 6–32, 113–118) Computers and associated controlling mechanisms or indicators are essential to the maneuverability of the spacecraft. Basic principles and application of circuits are used extensively for telemetry, instrumentation, and communications. Low voltage (28v DC) is used on more than 90% of the circuits. Extensive use of cabling requires careful analysis for servicing all types of circuits. (3B8, pp. 6–32) High voltage power sources employs back up or dual circuitry to assure constant voltage with little variation. Three-phase, four-wire power sources are evident for all telemetry and instrumentation circuits to assure dependability and reliability. Develop a typical aerospace circuit board employing indicator lamps, measuring devices, and protective equipment. Possible instrument panel board or computer circuit would be especially applicable.
Resistance, Voltage, and Current Controlling or Regulating Devices (Stand-By Generators) (Relays) (Crossbar Switching) (Solid State Controls)	Ground control system must have reliable power source. Dual service feed lines with automatic switching to alternate sources all performed by crossbar or solid state components. Extensive use of relays and microswitching evident in all parts of booster vehicles and capsules. Converters, inverters, transducers, sensors, and many other controlling or regulating devices are employed on both electrical and mechanical components. Almost all operate from the standard 24–28v DC system supplied from solar or fuel cells. These devices are some of the most important components in that the mechanical controls are dependent upon their proper functioning. A

LEARNING UNITS **AEROSPACE APPLICATIONS**

close correlation with cryogenics, thermodynamics, and hydraulics exists with these mechanisms.

Demonstrate the use of relays and converters in supplying power to model trains, cars, airplanes, etc. Hook up a three-phase, four-wire low voltage circuit and demonstrate automatic switching.

MAGNETIC EFFECTS OF ELECTRICITY
Natural, Artificial, Temporary, and Permanent Magnets

The basic theory of magnetism is not affected, but the number of applications and types of magnets used in space industry are tremendous. Increased knowledge of electromagnetic fields around the earth have become increasingly important. Magnetic metal forming, magnetohydrodynamic converters, magnetic flowmeter are only a few examples of new applications of long-standing principles. The generation and control by shielding of electromagnetic fields and permanent fields are also of importance.

Construct a magnetic flowmeter that will read the flow of a conducting liquid without offering any obstruction to the flow. (3B8) (3C9)

Solenoids and Electromagnets, Coils, Inductors, and Transformers

The numbers and types of these devices make it necessary to mention only a few applications. Almost all switching is done by solenoids, fuel control systems, vibration readouts, and the majority of the other 3,000 plus measurements that are taken on Saturn flights. Large power step up and step down transformers are used in transmission of electrical energy. Large electromagnets are used in metal forming. Transformers are used in all circuits and welders.

Make a small scale metal forming device that uses metal foil and electromagnets to supply the forming force. (3C6)

Magnetic Circuits and Applications

There are many new magnetic circuits that have been developed—magnetic core memory plates, magnetic tape computers, multichannel tape recordings (up to 8), electromagnetic flowmeter, magnetometers of high sensitivity, and plasma related magnetic circuits.

Demonstrate cutting of multichannel magnetic tape. Using sensitive compass, attempt to define magnitude and location of magnetic fields on this tape. (3B9)

Relays and Circuit Breakers

Relays and circuit breakers are innumerable. The basic theory and operation is unchanged. Applications for the most part are traditional. They are used in automatic control systems, readout communications relay systems, telemetry, and instrumentation circuits. Central power switchover equipment also makes extensive use of these.

Hook up a circuit employing a photo sensitive relay to control a model plane, car, or train. Attach same to a counter relay or timer relay to measure frequency or time differential.

Meters and Measuring or Testing Devices

Standard meter devices and meter movements basically the same but adapted to smaller scale for greater portability and space economy.

LEARNING UNITS	AEROSPACE APPLICATIONS
	Most readings are transmitted via telemetry to ground station, and there it is transferred by computer into readable form. Most test devices are composed of meters, scopes, and generators already used in the typical classrooms. Binary counters and clocks are extensively used.
	Construct a multimeter and hook this up to the pulsed circuit of a binary counter to measure voltage current and resistance readings.
Motor and Generator Applications (Generation) (Transmission) (Consumption of Power)	There were a multitude of motor generator applications. All movable gantry equipment is powered by diesel-electric or gas-electric generation system. All systems require emergency backup power generation equipment in case of power failure. Many fractional horsepower motors for moving systems, automatic cameras, directional antennas, and welding generators. Theories and applications are basically unchanged except for magnetohydrodynamic converters. Many different types of new applications are present in the complex of transmission lines and the necessary shielding to prevent interference between lines and outside stray transmissions. Frequent use of 400-cycle, three-phase circuitry requires special equipment associated with the aerospace industry.
	Hook up oscilloscope to motors and generators employing DC and various frequencies (25, 60, and 400 cycle) AC power. Determine the reason for use of each type of power as applied to each motor function. (3B8, pp. 82–85)
Inductance, Capacitance and Reactance, Time Constants, Network Circuits, and Resonance	Many uses of these basic principles found in shielding problems with reactors, controls, transmission lines, and special circuitry. Basic theory and application employed in many circuits especially telemetry and computer work, speed and timing devices, network circuits, and torque or stress measurements. Use of these was plainly evident in the computer and telemetry sections. Electrical discharge method of forming metal and Elox method of cutting involve use of capacitors for high voltage high current source.
	Construct an electrolytic tape device to detect leaks. Construct a variable capacitance tachometer to measure speed. (3C12) (3C14)
Rectifiers, Filters, and Special Circuits	Most onboard power requires no rectification. Already existing principles are numerous in ground support equipment. Basic source of power for all instrumentation, telemetry, and communications equipment is three-phase 208v AC with a four-wire feed. Each power supply unit is fed through dual hookup to each one of the phases on 110v thus providing three separate sources of power from main generator. Each power supply has its own rectification circuit.
	Construct a transistorized power supply to power a small battery operated transistor receiver similar to those employed in aerospace vehicles.
LUMINOUS EFFECTS OF ELECTRICITY	The efficiency of incandescent is usually very low (wasteful of power) and not especially useful for illumination in spacecraft. Fluorescent

LEARNING UNITS	AEROSPACE APPLICATIONS
Light and Its Uses for Illumination (Incandescent Effect) (Fluorescent Effect) (Hot and Cold Cathode Lighting) (Gaseous Bulbs Including Zeon and Other Repeating types) (Stroboscopic Effect) (Infrared)	light has a very low by-product of heat and is a good, basic source for cathode ray type projection. Both hot and cold cathode type is included. Perform an experiment measuring light emission characteristics of various light sources. Compare the current, voltage, and power required for each source. Compare advantages or disadvantages of each type. The principle of the repeater type gaseous tubes contrasts with the fluorescent units in that residual light emission is not required. Zeon tubes are used for measuring distance and direction characteristics in the space age. (3C11) (3C7) Demonstrate the Zeon tube with photographic strobe light and develop signaling techniques using standard code. The stroboscopic principle employs gaseous bulbs (seed) to measure the speed of light or of a moving object. Tracking and navigational equipment make use of this principle. It also has application for photographic concepts in space. Construct a simple stroboscope and measure the speed of moving parts. (RPM of a drill or speed of a propeller.) Attempt to photograph this with a strobe light on a camera.
Light and Its Uses for Generating Power	Solar cells are one of the most frequently used sources of power in space age applications. It is capable of delivering a continuous flow of power as long as it is exposed to rays of the sun. This source of energy can also serve effectively in charging more conventional batteries in space vehicles. Particularly useful to Apollo program. Unmanned satellites and special communications equipment must rely upon this source of energy since replenishing of fuel supplies is impractical. (3D1) (3D2) Develop a solar cell unit capable of supplying sufficient power to operate a small transistorized radio or transmitter. Install a solar cell unit in a model car to provide the source of power. *Note:* Many good experiments and components are available through electronics equipment distributors. Also Bell Telephone Labs provide excellent line demonstrations and/or kits for school use.
Light As Used to Generate Heat	The capability of solar cells to produce electrical power permits this energy to be transmitted to and used at inaccessible locations remote from light source. (3B8) (3B1) Solar furnaces have direct application for heating space vehicles. Extreme variations in temperature in outer space necessitate provisions for both heating and cooling the vehicle to protect human life as well as delicate or sensitive components. (3B8) (3B1) Construct a small solar furnace employing the use of parabolic

Fig. 3–3. The Mission Control Center is base for tracking and communications operations.

reflectors, solar cells, and small drive motors and apply this to the heating of a small model house, animal shelter, greenhouse, or arboretum.

Light and Light Waves and Their Use in Communications
(Controlled Lighting)
(Photometry
(Spectroscopy)
(Photo Cells)
(Laser)

Extensive use of controlled or indicator lighting is found on instrument panels of space vehicles and ground stations. All types of warning, indicator, and visibility lights are evident. In most all cases low voltage and low current bulbs or indicators are employed. These are particularly used in control headquarter's equipment. Fig. 3–3. (3B8)

Photometry is the basic principle of light measurements available for the purposes of photography or photogrammetry in space. These principles are necessary for carrying back information of scientific nature from space stations or planetary vehicles. Incorporated into telemetry signals, live transmissions can be recorded as in the case of the moon shots. (3D4) (3D3)

Spectroscopic principles are applied to space travel navigation. Light intensity measurements from the stars will assist space travelers in determining orientation, distances, and time. Doppler effect is also an important aspect of this basic principle. (3B1)

Photo cells and laser applications are used for interference free com-

munications principles. These principles are particularly useful and are already applied to the television spectrum of frequencies. (3B8) (3A2, pp. 281–294)

Experiments using spectroscopes and photo cells can be applied to light intensity measurements. The student could construct photo cell relays to open and close doors, turn on and off lights, or transmit and receive AM signals on a light beam.

THERMAL EFFECTS OF ELECTRICITY
Wire Sizes and Resistance of Materials
(Power Dissipation)
(Current Capacity)
(Insulation Effects)
(Thermal Wire Stripping)

Extensive use is made of all sizes and styles of conductors throughout space industry. It is quite evident that quality and reliability of the proper size, materials used, insulation or shielding, and proper termination or connection is of fundamental importance to all parts of the space vehicle and its supporting launching, communicating, or control facilities. (3B5) (3B8)

Low voltage, low current conductors are used in most cases with DC utilized in more than 90% of the circuits. Extensive use of multiconductor cable and connectors is evident. Most components and exposed terminals are coated or encapsulated to protect them from adverse atmospheric conditions which could cause electrical malfunctions. Power and heat dissipation of components are given high consideration. Heat sinks are used in most power transistor circuits. (3C3)

Solder connections are used more frequently than mechanical joining for circuit components. This is done because of the severe vibrations which the electrical equipment must endure. Thermal wire strippers are employed to remove insulation from wires. (3B5) (3B6)

Construct a transistorized circuit board using space vehicle components associated with an instrument panel. Solder the connections, seal or coat the components, and test for heat rise characteristics before and after. Examine a heat sink and apply to the circuit.

Heater Type Components and Their Function
(Heating Effect of an Electric Current)
(Thermostats and Thermocouples)
(Thermistors)
(Thermionic Converters)

Heat characteristics of an electric current can be both an asset and a liability for space age applications. In some cases, such as piezo electric crystals, heat is used to stabilize their frequency. Heat is also desirable to prevent the accumulation of moisture or condensation in electronic equipment. In other instances radiated heat from the space vehicle equipment may exceed the normal capacities desired for equipment operation or human comfort. In turn, air conditioning becomes necessary. (3B8)

The negative heat characteristic of thermistors tends to balance the heat dissipation of resistors in space electronic equipment.

Thermostats and thermocouples are frequently used to control current flow to the navigational and telemetric equipment as well as the biological sensors or space capsule heating or air-conditioning equipment.

Thermionic converters are used to generate electricity and are valuable

to space age applications in that there are no moving parts involved. These can be vacuum, plasma, solar, nuclear, or cesium. They can produce either direct or alternating outputs.

Hook up a circuit using both resistors and thermistors. Observe the variations of current flow as heat is applied to each. (3B8)

Resistance Welding
(Arc)
(Spot)

Welding is used primarily on the structure of the capsule and on all supporting or assembling mechanisms. Extreme care is exercised in assuring continuous welded joints to prevent corrosive effects. (3B7)

CHEMICAL AND STORAGE EFFECTS OF ELECTRICITY
Cells and Batteries
(Characteristics of Cells)
(Charge and Discharge of a Storage Battery)
(Conductivity of Solutions)
(Metal Alkaline Battery)
(Biochemical Cells)
(Fuel Cells)
(Silver Zinc Battery)
(Nickel Cadmium Battery)
(Dry Type Battery)
Capacitors and Dielectrics
(Filters)
(Insulator Layers)

Cells and batteries are used extensively in space vehicles and ground support equipment. In most cases they provide power (24–28vDC) for operating all types of communications, telemetrics, and instrumentation equipment. Each of the items listed to the left have specific application to at least one form of space equipment. In some cases, such as in the fuel cell, the functioning of this unit in turn provides water which can then be used by man in space. For long term space flights other sources of power, such as solar, thermionic, or magneto, hydrodynamic converters are being considered and used.

Ground support units use cells and batteries for emergency lighting, telephone, portable equipment, and transportation and lifting vehicles.

Construct a fuel cell and make use of the water by-product as applied to a space vehicle. (3A1)

Many types of capacitors are used in aerospace vehicles. Evidence of miniaturization of components is quite apparent with use of exotic materials as dielectrics.

There is an increasing tendency to go toward reflective layers using dielectric films and special sensor materials for the skin response mechanisms. Metallic fiberglas is used in capacitor components with laminated multiple construction a consistent feature of the smaller capacitors.

Extensive filtering is evident on all power sources to keep output constant and prevent dumping of computers or data processing equipment used in telemetry and communications equipment.

Network circuits require frequent use of Rand C circuits for the counter or timing devices. These incorporated with transistors form the basic nucleus of binary circuits.

Construct a binary counter circuit involving one or more flip-flops and capable of counting up to 15. (3C8)

Electrolysis, Electroplating, Anodizing, and Etching
(Contacts and Anodes)
(Liquids and Solids)

Space vehicles are subject to wide variations of atmospheric conditions resulting in oxidation. Serious attention is given to the following:

Prevention of electrolysis or corrosion between dissimilar materials, particularly at electrical connections.

LEARNING UNITS	AEROSPACE APPLICATIONS
(Electroforming) (Fluorocarbon Polymers) (Types of Boards) (Materials Used) (Solder and/or Adhesives) (Tolerances) (Connectors) (Modular Packaging)	Carefully etched and plated or coated circuit boards and contact points or component parts. Fuel cell characteristics with particular emphasis upon controlled electrolysis. Use of precious metals and special resins having a high insulation characteristic with very light coating. Use of electroforming and fluorocarbon techniques which involve use of fluids in the process.

Anodizing is used extensively on handrails, nuts and bolts, component parts, cabinets, metal surfaces exposed to extreme atmospheric conditions, and antenna systems.

Etching of printed circuits is one of the most evident features of telemetric and instrumentation equipment.

Construct a printed circuit board and demonstrate etching and plating techniques on same. Use space industry components and soldering or connecting standards. Test corrosive and insulative characteristics when complete. (3C1) (3C2)

Ferroelectric Bolometer Measures RF Absolute Power at Submillimeter Wavelengths

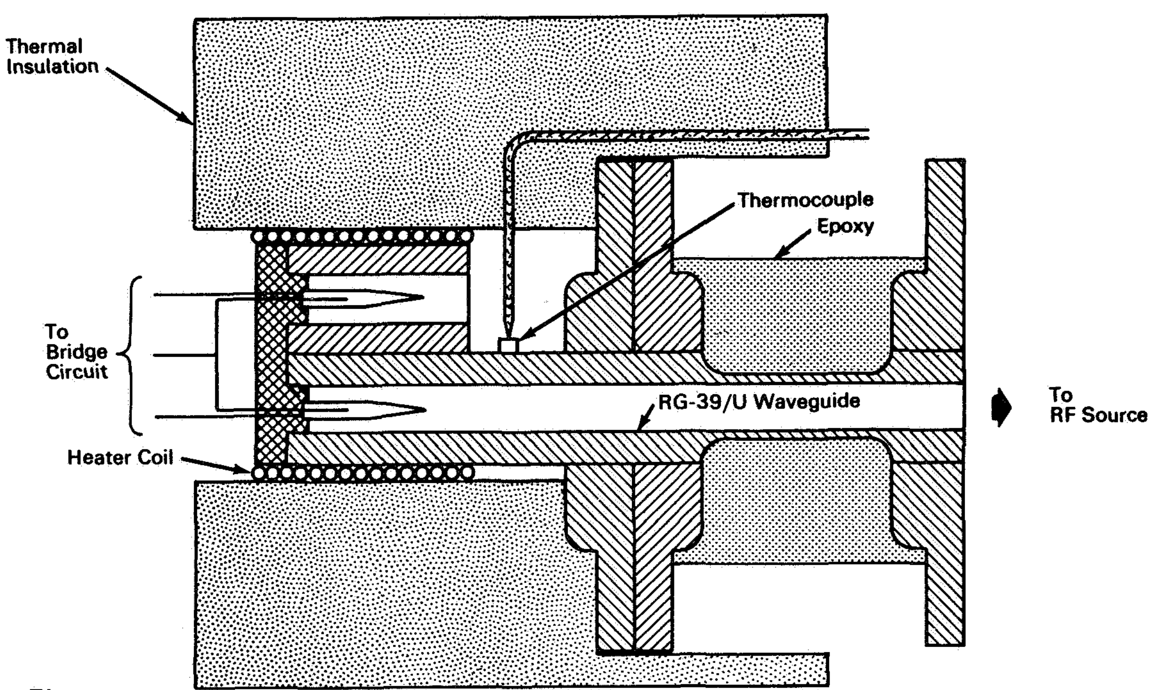


Fig. 3-4.

LEARNING UNITS	AEROSPACE APPLICATIONS
BASIC COMMUNICATIONS AND SOUND EFFECTS Waves and Wave Motion (Crystals) (Sound Waves) (Shock Waves) (Ionic Plasma Waves) (Light Waves) Telephone and Telegraph	Sound, radio, light, and, in fact, almost any type of wave form or motion is involved in space travel. Radio and telemetry signals are used for communication and control. Vibration and shock waves must be overcome to maintain stability through thrusters. Crystals are used to stabilize transmitters. (3B2) Extensive use of telephone and telegraph. Used to communicate with tracking stations and other control centers. Pulse modulated signals on telemetry circuits is a fundamental concept of the space age. (3D6) (3B3) (3B4) (3C16) Fig. 3–4.
BASIC ELECTRONICS AND COMMUNICATIONS The Vacuum Tube, Its Function and Characteristics (Receiving) (Transmitting) (Special Purpose)	Power supply sources and heavy radio, radar, and other transmitting equipment make use of the vacuum tube for heavy current and high wattage outputs. Construct dual-voltage power supply to deliver two different DC filtered output voltages per circuit. (3C5) Fig. 3–5.
Semiconductors, Transistors, and Solid State Components	Used extensively in computer equipment, telemetry circuits, and space capsule equipment. Strain gauges, sensors, and other delicate instruments requiring low current and small space also use these items. From selenide material construct and test a solid state diode rectifier. (3C10) (3C13)

Dual-Voltage Power Supply Has Increased Efficiency

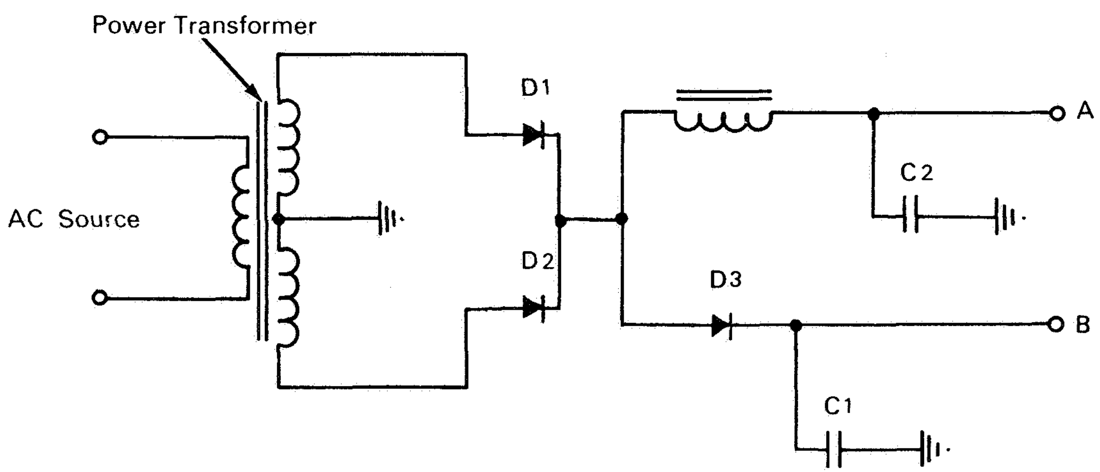


Fig. 3–5.

LEARNING UNITS

Audio Functions, Components, Circuits, and Controls
(Range of Audio)
(Types and Classes of Amplifiers)
(Coupling and By-Passing)
(Phase Splitting and Inverting)
(Push-Pull Operation)

AEROSPACE APPLICATIONS

Intercommunication equipment, carrier amplification, and telemetry pulsing are all direct applications of these principles. Vacuum tubes, transistors, and other semiconductors are used. Network circuits for binary counters are quite evident.

Design and build a simple transistorized intercom using push-pull output and phase inverter circuitry. (3B8, pp. 119–144)

Antenna Configurations Provide Polarization Diversity

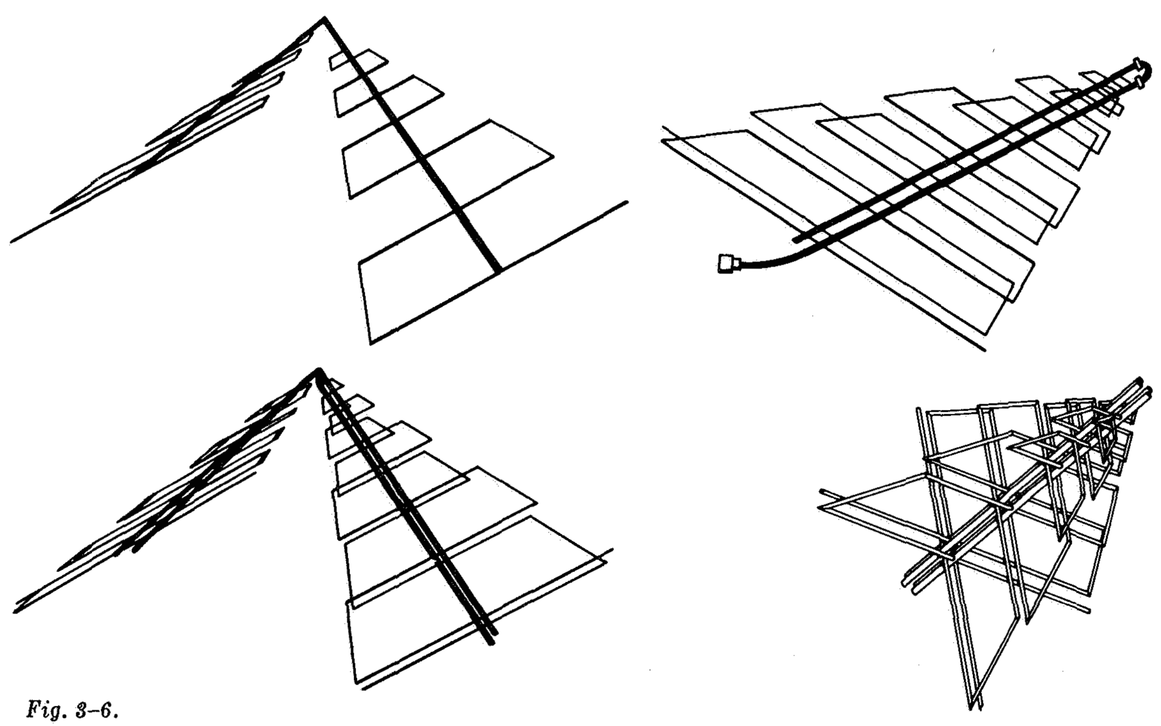


Fig. 3–6.

Transmission of Signals with Components and Function
(Oscillators)
(Multivibrators)
(Detectors)
(Modulators)
(Antennas and Systems)

Radio, radar, television, and telemetry equipment employ all of these circuits in basic communications. (3D5)

Antenna systems of all types are employed for communication tracking and control equipment.

Using a simple AC/DC Receiver W/loop antenna, disconnect loop and note loss of signal. Connect receiver to long wire and note signal difference. Reconnect to loop and note directional characteristics. (3C15) (3C4) Fig. 3–6.

SAMPLE TEACHING UNIT
ELECTRICITY-ELECTRONICS

A. Background

Thermistors are an important part of the electronics industry with particular reference to their use in aerospace vehicles.

B. Motivation

1. Thermistors are very compact in size and light in weight.
2. They are easily adaptable to spacecraft applications and function.
3. The scientific theories represented by their use are quite broad to include many areas of science.
4. Present and future anticipated use of these components for space vehicles affords an almost unlimited number of future job opportunities for people to be employed in research and development.

C. The Organization of Content

1. To study the nature, construction, and functioning of thermistors.
2. To interpret diagrams of simple circuits using thermistors.
3. To collect and analyze data concerning comparisons between types of thermistors and their use.
4. To apply the findings to other instructional units in Electricity-Electronics.

D. Materials and Equipment

1. Assorted resistors
2. Hook up wire
3. Switches
4. Voltmeter, ammeter, and ohmeter
5. Power source
6. Circuit boards

E. Suggested Content to be Studies

1. What are thermistors?
    a. Measurement of temperature
    b. Regulate current flow
    c. Control or protect circuits
2. Where are thermistors used?
    a. Aerospace vehicles
    b. Sensitive instrumentation circuits
    c. Telemetric circuits
3. What is the nature and composition of thermistors?
    a. Temperature affects all components.
    b. Resistance and heat characteristics of all materials are variable.
    c. Positive and negative temperature characteristics

Note: The above to be performed by research and experimentation technique supplemented by instructor demonstration.

F. Conclusions

1. Thermistors can be excellent current regulating devices in certain

types of applications.

2. Negative temperature characteristics are desirable in certain components to offset other heat rise equipment.
3. Trend toward miniaturization of parts necessitates use of highly efficient components.

G. Resource Material

3A1 Buban and Schmitt, Understanding Electricity and Electronics.

3B2 Advanced Research—Key to the Future.

3B8 Conference on New Technology.

REFERENCE MATERIALS

ELECTRICITY-ELECTRONICS

(Film List—See Appendix II, page 161)

3A1 Buban, Peter and Schmitt, Marshall. Understanding Electricity and Electronics. New York: McGraw-Hill Book Co., 1962.

3A2 Gerrish, Howard. Electricity and Electronics. Homewood, Illinois: The Goodheart-Willcox Co., Inc., 1963.

3B1 NASA EP–6 (Revised) Space—The New Frontier, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.75

3B2 NASA EP–19–64 Advanced Research—Key To the Future, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.20

3B3 NASA SP–11 Proceedings of the NASA-University Conference, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

3B4 NASA SP–43 Ariel I, The First International Satellite, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.50

3B5 NASA SP–5002 Reliable Electrical Connections, Office of Technical Services, Department of Commerce, Washington, D.C. 20230. $.70

3B6 NASA SP–5010 Selected Shop Techniques, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.25

3B7 NASA SP–5011 Welding for Electronic Assemblies, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.40

3B8 NASA SP–5015 Conference on New Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

3B9 NASA SP-5038 Magnetic Tape Recording, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.25

3C1 *NASA Tech Brief 63-10612
3C2 NASA Tech Brief 64-10118
3C3 NASA Tech Brief 66-10004
3C4 NASA Tech Brief 66-10066
3C5 NASA Tech Brief 66-10002
3C6 NASA Tech Brief 66-10045
3C7 NASA Tech Brief 66-10046
3C8 NASA Tech Brief 66-10070
3C9 NASA Tech Brief 66-10073
3C10 NASA Tech Brief 66-10089
3C11 NASA Tech Brief 66-10096
3C12 NASA Tech Brief 66-10099
3C13 NASA Tech Brief 66-10106
3C14 NASA Tech Brief 66-10126
3C15 NASA Tech Brief 66-10129
3C16 NASA Tech Brief 66-10051
3D1 †NASA Facts Vol. III, No. 7
3D2 NASA Fact Sheet 292
3D3 NASA Facts Vol. II, No. 6
3D4 NASA Facts Vol. II, No. 12
3D5 NASA Facts B-12-62
3D6 NASA Facts Vol. II, No. 14

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section 2

UNIT 4—POWER

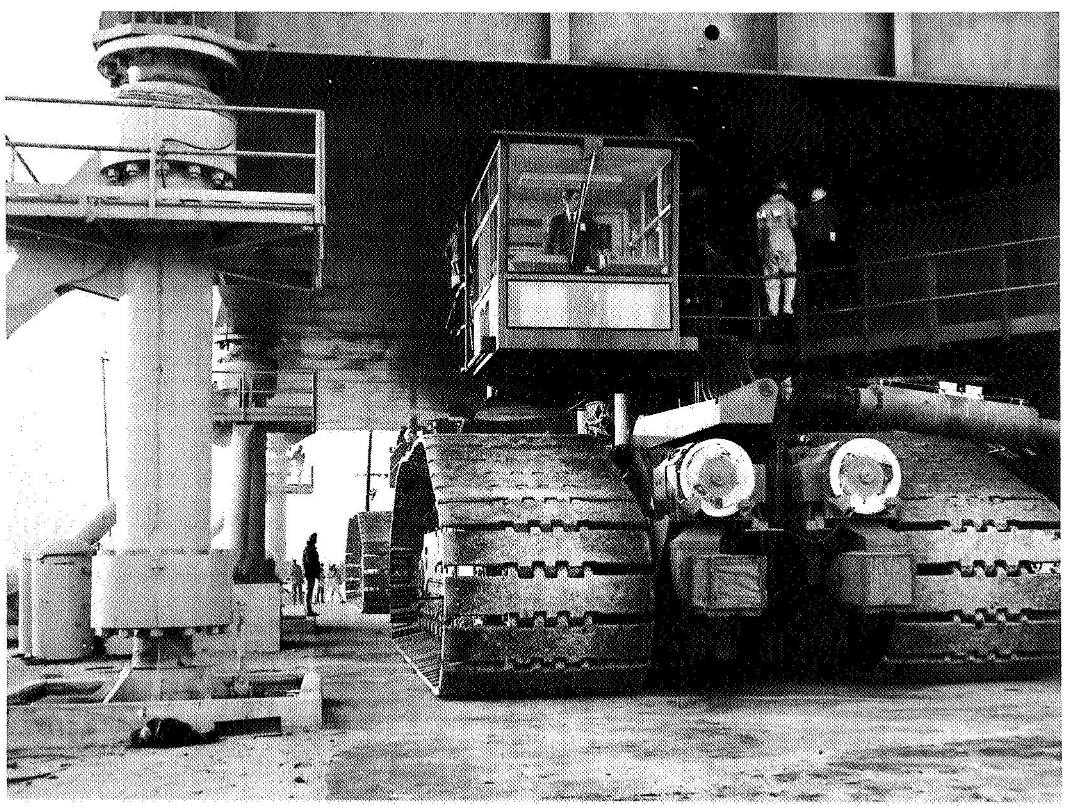
INTRODUCTION

This chapter illustrates some space concepts in power instruction that can be applied to a course in power or auto mechanics. However, this outline is not a course in power.

The concepts or applications listed are but a few that apply to this broad area of power. New ones are being identified each day. This chapter is intended to serve as a stimulus for the instructor to start using space industry material.

The study of rocket engines, energy converters, nuclear power, cryogenic and atomic fuels are completely in the realm of the space industry study and, therefore, are not treated heavily in this chapter. Several textbooks on power cover these areas quite thoroughly and are recommended for the instructor who wishes to provide a comprehensive study of these topics. Many new power requirements are also to be found in the space industry which lead to the development of equipment of a more conventional nature. Fig. 4–1. A study of both the new and the conventional proves very interesting.

Fig. 4–1. The crawler/transporter being positioned beneath the launcher. This is an example of one of the many kinds of power equipment needed in the space program.



LEARNING UNITS	AEROSPACE APPLICATIONS
HISTORY OF POWER DEVELOPMENT Muscle Water Wind	Our principle sources of power were all developed in the last 250 years. What are the expectations for the next 10 years? 50 years? (4F7)*
MEASUREMENT OF POWER Laws of Measurement of Force, Work, and Energy	Power is measured in pounds of Thrust; A force produced by expelling a propellant. $F = \frac{\dot{w}}{g} V$ $\dot{w}$ = propellant mass flow rate per second V = propellant exhaust velocity g = conversion factor, mass units to weight units ft/sec²
Horsepower	Specific impulse, the amount of thrust derived from each pound of propellant in 1 second of engine operation, is expressed as: $I_{sp} = \frac{\text{Force}}{\text{Weight/sec}} = \text{sec.}$ Thrust/Weight ratio, a comparison of the booster's thrust with the vehicle's total weight: Booster's $\frac{F}{\dot{w}} > 1$ (4D6)
INTERNAL COMBUSTION ENGINES Two-Stroke Cycle Four-Stroke Cycle Assembly-Disassembly	Small gasoline engines are used at the launch site on stand-by and emergency machines. The awesome sight of million pound thrust engines contrast dramatically with two and four-cycle engines on water pumps, air conditioners, coolers, and emergency generators. Compare the problem of assembly or disassembly of engine parts on the ground and in space. Analyze one skill, such as tightening a nut using a box-end wrench. What modification to the wrench or to the nut must be made under weightless conditions? What changes in human motions are necessary?
Engine Design and Types Lubrication of Parts	Study the reaction of ordinary lubricants in a weightless situation. How is the aerospace industry solving this problem. (4B1, pp. 91–96) (4C5) (4C11)
Cooling of Parts	Cryogenic fuels are used in many rockets. These extremely cold liquids are used to cool the nozzle of the thrust chamber. This nozzle is actually a honeycomb of tubes and fins much like a water cooled radiator of an automobile. (4A1, p. 266) (4A2, p. 45)
Ignition	Ignition of fuels in the X–15 rocket engine is much the same as the spark ignition of conventional engines. (4A1, p. 268) (4A2, p. 50) Doctor Robert Goddard's first rocket engine had an igniter made of match heads packed into a tube, a very dangerous procedure. (4D5)

*See page 9 for Reference Code.

LEARNING UNITS | **AEROSPACE APPLICATIONS**

Air-Fuel Intake

In conventional engines the problem is to have a clean air-fuel mixture of the proper proportion. The space industry is faced with this problem plus the additional problem of providing a combustable agent outside the earth's atmosphere and greatly increasing the combustion rate.

Changes in engine power due to oxygen supply can be simply demonstrated as follows:

Gradually decrease the air (oxygen) supply until the engine nears a stall condition.

Increase air supply until engine runs smoothly.

Analyze the results and relate them to the space problem of increasing combustion rate.

Because rockets must have a self-contained fuel supply in order to function in space, the fuel and oxidizing agent are stored in separate tanks and mixed under pressure. How does this differ with fuel intake and mixture of gasoline engines?

Function of Piston, Rods, Crankshaft, and Camshaft

Engine torque is counteracted by design of mounts. Eliminate the fuel and air supply; then list the many conditions that would prohibit the use of a reciprocating four-stroke cycle engine in a space vehicle.

Tools

Many special tools are being developed by the space industry, many of which may be of use to the auto mechanic. Some of these are listed below.

A T-handled torque wrench with pre-set torque release. (4C17)

Because of the restricted space for movement in some engines, a special torque wrench was developed which uses the principle of a motorcycle handle bar control. (4C20) Fig. 4–2.

Torque Wrench Designed for Restricted Areas

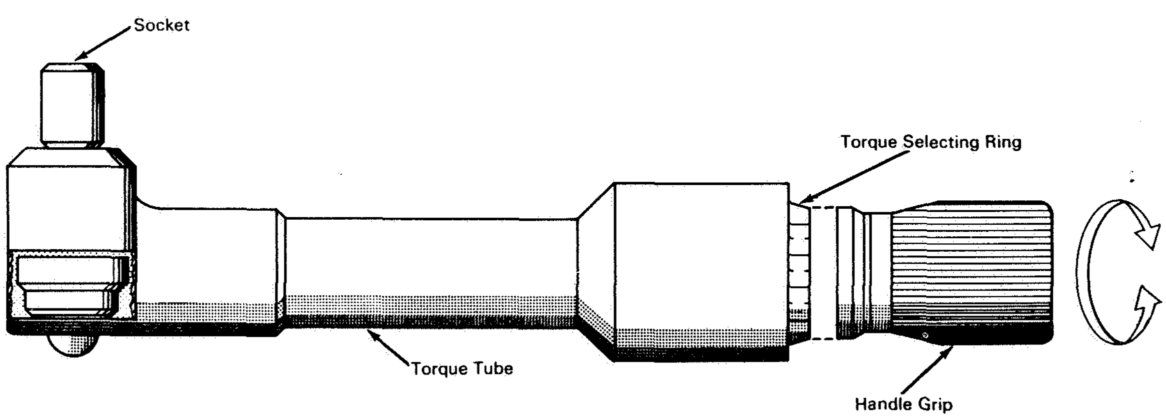


Fig. 4–2.

AEROSPACE APPLICATIONS

The wide uses of sensors and transducers identify and locate the minutest malfunction in rocket engines should lead to the development of more sophisticated analysis equipment for automobile engine servicing and trouble shooting.

Diesel Engines

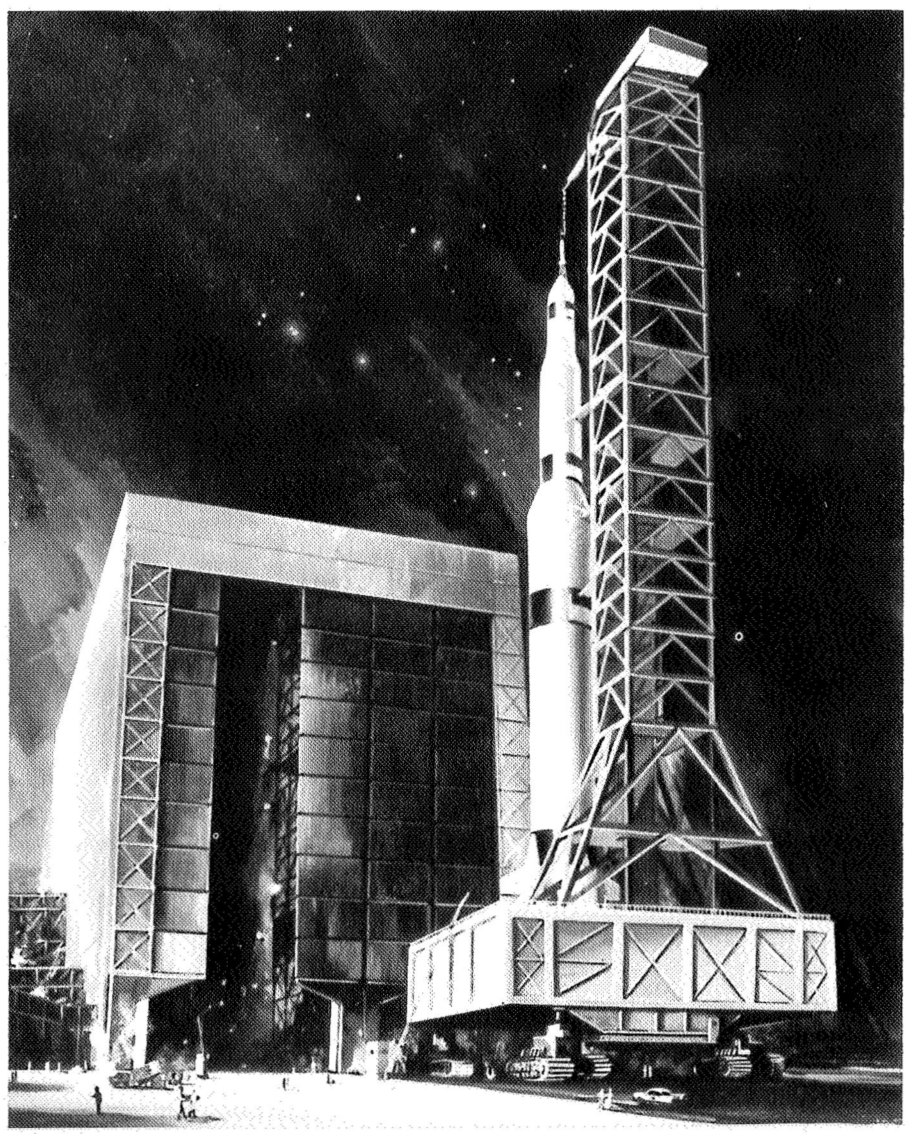
Diesel engines are in evidence throughout the space launch facilities. They are used on stand-by equipment and for emergency power generation.

Perhaps the most vivid use of diesel power in aerospace activity is demonstrated in the crawler/transporter which will transport Saturn V launch vehicles and their launchers (mobile) from the Vehicle Assembly Building to the launch pad.

This vehicle weighs 6,000,000 pounds, is 131 feet long, and 114 feet wide. It moves on 4 double track crawlers, each 10 feet high and 40 feet long. Each pad weighs about 1 ton.

This vehicle is powered by two, 5500 horsepower diesel engines. Two other diesels generate 2130 horsepower for leveling, jacking, steering, lighting, ventilating, and electronic controls. (4D7) Fig. 4–3.

Fig. 4–3. The crawler/transporter vehicle in operation.



LEARNING UNITS	AEROSPACE APPLICATIONS
Aircraft Engines	Research into aircraft of the future is one of the objectives of the aerospace industry. One such project is the supersonic airliner. (4B6) NASA has developed an aircraft that is capable of taking off and landing vertically. Rather than use the rotor blades of a helicopter, the entire wing with motors attached is tilted. (4D1)
CONTINUOUS INTERNAL COMBUSTION ENGINES Gas Turbine Engines	Space industry application of the gas turbine engine can be found in the larger helicopters used in search and recovery operations and in the experimental aircraft, such as V-STOL. (4D1)
Airstream Reaction Engines (Jet)	A class activity to show the action-equals-reaction effect requires only a long balloon, a paper straw, and a wire stretched between two points. Release an inflated balloon. Note its path. What makes it move? What controls its direction? Tape the paper straw lengthwise to the inflated balloon. Thread the wire through the straw and stretch it tight. Release the balloon, allowing it to deflate. Now note its path. A more realistic demonstration can be done by fastening a CO_2 container to a bicycle wheel. When the CO_2 is released, it will cause the wheel to turn. Does the force of the escaping gas against the outside air cause the movement?
Rocket Engines	Rocket engines differ from jet engines in that they have a self-contained fuel supply, such as liquid hydrogen as the fuel and liquid oxygen as the oxidizer. Jet engines use oxygen from the atmosphere. Therefore, the rocket engine can function outside the earth's atmosphere. (4D6) A self-contained fuel supply can be demonstrated in the shop by using an acetylene welding unit. The fuel is acetylene and the oxdizer is oxygen. Ignite the acetylene. The result is an orange flame with much carbon residue. This would indicate that not all the acetylene is being burned. The atmospheric oxygen is not sufficient. Add oxygen to the acetylene while it is burning. When the proper mixture is attained, the flame will burn clearly. Add still more oxygen. Without adding fuel, you should have a longer, hotter flame. If these fuel and oxidizer containers were small enough in relation to the torch and if the combustion took place in a chamber with an aperture (nozzle) of the correct size, the combustion could propel the unit.
Liquid Fuel Engines	On March 26, 1926, Dr. Robert Goddard launched the first liquid fuel rocket at Auburn, Massachusetts. (4B2, pp. 11–13) (4B3, pp. 3–6) (4B2, pp. 10–12) (4D5) The X–15, the first experimental rocketpowered winged vehicle,

achieved many notable records and in doing so developed many useful devices now used in aerospace rockets and capsules. (4B9)

A graphic comparison of vehicle size, thrust power, engine size, and fuel systems of many space vehicles shows the progress made in the space industry. (4D2)

Solid Fuel Engines

In 1232 AD, the Chinese used solid fuel rockets in warfare. These were much like our skyrockets. (4B2) (4D4)

The skyrocket is a simple solid fuel engine which used a black powder mixed with some ingredient to slow the burning process. The fuel is carbon and sulphur, and the oxidizer is potassium nitrate (KNO_3). (4A1, p. 272) (4D6) (4A2, pp. 128–135)

Different configurations of fuel and inhibitor makes it possible to control the burning speed. Neutral burning charges, progressive burning charges, and restricted burning through use of inhibitors are all factors of design of solid fuel to make it perform as desired. (4A1, p. 271) (4A2, pp. 128–135)

An activity to demonstrate solid fuel would be to attach a solid fuel engine to the bicycle wheel in place of the CO_2 container. These miniature engines are available through supply houses. (4F5)

JATO, Jet Assisted Take Off, is an application to military and commercial aviation. (4A1, p. 273) (4A2, pp. 128–135)

The solid fuel SERGEANT has replaced the liquid fuel CORPORAL antimissile missile. The PERSHING solid fuel missile has replaced the REDSTONE. Solid fuel boosters are strapped to the sides of the Titan series of engines for additional thrust. (4A1, p. 273) (4A2, pp. 128–135)

Solid fuel engines have no cryogenic problem.

EXTERNAL COMBUSTION ENGINES
Stream Engines
Steam Turbine Engines
Fossil Fuel (Steam Generators)
Atomic Fuel (Steam Generators)

ENERGY TRANSMISSION
Simple Machines

Many aerospace problems have been solved through the knowledge of simple machines. (4B5)

The door operating system of the Vehicle Assembly Building at Cape Kennedy is quite simple in nature even though it must be opened to a height of 456 feet. The doors are 149 feet wide at the bottom. (4D3)

This building has been described as "not so much a building to house

a moon vehicle as a machine to build a moon craft." (4D3)

A simple semicircular rack and pinion system is used to open the launch structure in the Saturn V complex.

Scaffoldings that will be used to assemble the stages of the Saturn V are adjustable in height by a large pin in each of the four corners.

ENERGY CONVERTERS

Mechanical

Movable permeable tape with a cathode and electrolyte material may be drawn across an anode to produce electrical power. (4C9)

Chemical

The development of many modern batteries with unusually long life has been one of the major space industry contributions. (4B1, pp. 65–70)

Thermal

The space industry's research into heat conduction and effect has contributed to the further development of thermoelectric generation. (4B1, pp. 72–74, 85–89)

Ion Generators

Major emphasis is being placed on MED (magnetohydrodynamic) generation. The use of ionized gas (plasma) is being thoroughly researched for use in the space industry. (4B1, pp. 82–85)

Solar

Although the development of solar cells came before the space age, their refinement and utilization has been greatly accelerated by their use in space exploration vehicles. (4B1, pp. 70–72)

Fuel Cells

Fuel cells are a form of battery with their ingredients outside the case. They are not new, but their apparent usefulness in space travel make them a research item for the space industry. (4B1, pp. 74–78, 113–118)

Excess water produced by fuel cells becomes a problem. It is removed by reaction heat. (4C19)

Pratt and Whitney Corporation is carrying on an active research program on fuel cells. (4F1)

Nuclear

Project "Rover," America's program to develop a nuclear propelled rocket, is a joint AEC and NASA program. Scientific and technological aspects of the program are the responsibility of the University of California's Los Alamos Scientific Laboratory. (4F3)

Doctor Glenn T. Seaborg discusses "Nuclear Power in Space." (4F4, pp. 1–11)

Colonel William A. Tesch remarks on the "Advanced Space Electric Power Program." (4F4, pp. 21–27)

ENERGY TRANSMISSION

Complex Machines

Listed below are the solutions to several problems that blocked success in the space program.

One problem was to store a cylindrical boom in a space capsule. This boom would be used as a leveling device or a sample taking bore. (4C3)

The design of a magnetic brake to be used for a soft stop is explained

LEARNING UNITS **AEROSPACE APPLICATIONS**

by use of mutual conductance. (4C6)

A noncontacting torque measuring device uses magnetic measurement. (4C18)

A mechanism to continuously measure the dynamic and static load on a cable by use of a strain gauge has been invented by a NASA employee. (4C13)

Hydraulic Transmission

The crawler/transporter used to move the Saturn V, its mobile launcher, and its mobile service tower is a complex system of electrical and hydraulic power control systems. The machine uses hydraulic jacks to raise its load of 11½ million pounds, keeps it level at all times, and transports it 3½ miles to the launch pad. (4D7)

The mobile launcher and the service tower are leveled and stabilized when parked by use of hydraulic jacks and braces.

Hydraulic power is used in special metal forming techniques. (4B4)

By welding the special fitting to the ends of hydraulic tubing and using an "O" ring, quick, leakproof connections may be made. (4C15)

Pneumatic Transmission

Sensing devices and transducors make use of pneumatic transmission in the telemetry system.

An air-bearing measuring device is a simplified tool for determining deviation from parallel of precision parts. (4B7, pp. 13–14)

The use of bottled gas to operate remotely located railroad switches solves the problem of long supply lines. (4C12)

FUELS AND LUBRICANTS
Fuels

The space industry has done much research into the removal of all impurities from the fuels used in all types of engines. Below are listed some of the techniques used.

A system to detect hydrocarbon content in fuel lines was devised to stop malfunctions and to save time. (4C2) (4C7) Fig. 4–4.

Sensor Detects Hydrocarbon Oil Contaminants in Fluid Lines

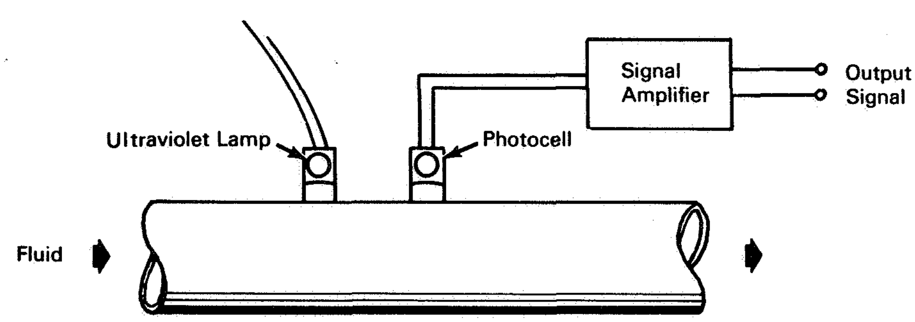


Fig. 4–4.

Fuel leaks in insulated tanks or lines can be detected without the use of tracers. (4C4)

Fuel flow rate can be supplied on demand for aerospace use. (4C8) (4C16) Fig. 4–5.

A self-actuating, self-monitoring valve was devised for cryogenic materials to keep them in a liquid state as they enter the system.

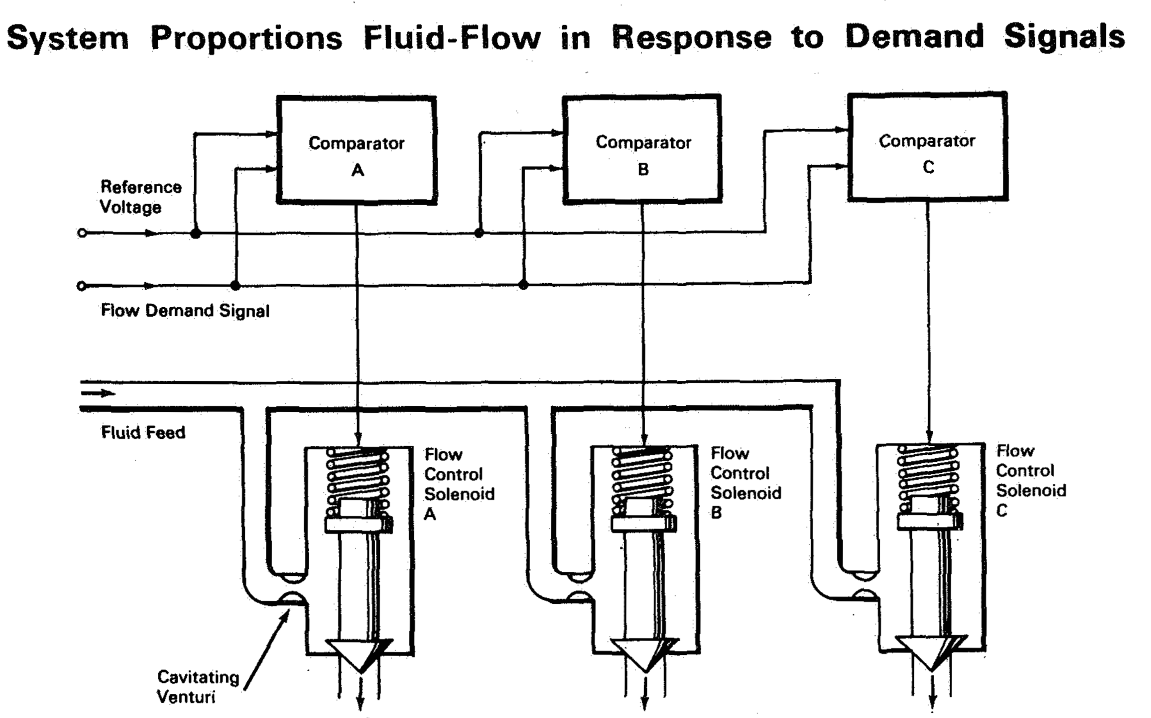


Fig. 4–5.

Lubricants

One-third to one-half of all the energy produced in the world is lost in friction. Space industry equipment poses even a greater lubrication problem. Bearings and valves must operate in cryogenic fluids, such as liquid oxygen and hydrogen, and also in extreme heat up to 1200° F. or higher. Weightlessness also creates some startling lubricating problems. (4B1, pp. 91–96)

The use of fluoride coating as a lubricant for extreme high and low temperatures is discussed. (4C5)

A solid film of calcium fluoride and a suitable inorganic binder may be fused to a surface to provide lubrication at high temperatures in a vacuum. (4C10)

Polytetrafluorethylene lubricates ball bearings in a vacuum environment. (4C11)

Chemical additives are used to prevent scoring of highly loaded gears of a turbopump. (4C1)

SAMPLE TEACHING UNIT

POWER
FUEL AIR INPUT

OBJECTIVES	STRATEGY	SPACE APPLICATION	RESOURCES
The student should learn: 1. Fundamentals of carburetion. 2. Principles of the fuel pump. 3. Carburetor parts and system. 4. Relationship between fuel input systems of gasoline engines and rocket engines.	1. Sketch a simple fuel circuit. 2. Disassemble a carburetor. 3. Adjust idle speed and mixture. 4. Adjust float level. 5. Disassemble fuel pump and trace fuel flow.	Compare air supply of small engine with that of rocket. With engine running, reduce air supply until engine begins to choke. Increase air supply until engine runs smoothly. By use of welding torch, add oxygen to air intake. Evaluate results and draw a conclusion. Compare the use of a fuel pump on an automobile with the fuel pump on a liquid fuel rocket.	Rochester Service Manual A.C. Fuel Pump Manual Carter Fuel Pump Manual *Let's Study Carburetors,* Hot Rod Magazine, December, 1957. Duffy, Joseph W. *Power—Prime Mover of Industry.* Bloomington, Illinois; McKnight and McKnight, 1964. pp. 262–287. Stevenson, George E. *Power Mechanics.* Albany, New York: Delmar Publishers, Inc., 1963. pp. 128–135.

REFERENCE MATERIALS

POWER

(Film List—see Appendix II, page 161)

4A1 Duffy, Joseph W. Power—Prime Mover of Technology. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1964.

4A2 Stevenson George E. Power Mechanics. Albany, New York: Delmar Publishers, Inc., 1963.

4B1 NASA SP–5015 Conference on New Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

4B2 NASA EP–6 (Revised) Space—The New Frontier, Superintendent of Documents, U.S. Government Printing, Office, Washington, D.C. 20402. $.75

4B3 NASA EP–29 Historical Sketch of NASA, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.50

4B4 NASA SP–5017 Metal Forming Techniques, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.40

4B5 NASA SP–5010 Selected Shop Techniques, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.25

4B6 NASA EP–19–64 Advanced Research—The Key to the Future, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.20

4B7 NASA SP–5013 Precision Tooling Techniques, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $.25

4C1 *NASA Tech Brief 66–10069
4C2 NASA Tech Brief 66–10068
4C3 NASA Tech Brief 66–10032
4C4 NASA Tech Brief 66–10099
4C5 NASA Tech Brief 66–10005
4C6 NASA Tech Brief 66–10073
4C7 NASA Tech Brief 66–10090
4C8 NASA Tech Brief 66–10094
4C9 NASA Tech Brief 66–10098
4C10 NASA Tech Brief 66–10087
4C11 NASA Tech Brief 66–10081
4C12 NASA Tech Brief 66–10124
4C13 NASA Tech Brief 66–10107
4C14 NASA Tech Brief 66–10136
4C15 NASA Tech Brief 66–10021
4C15 NASA Tech Brief 66–10036
4C17 NASA Tech Brief 66–10065
4C18 NASA Tech Brief 66–10048
4C19 NASA Tech Brief 66–10013
4C20 NASA Tech Brief 66–10011
4C21 NASA Tech Brief 66–10008
4D1 †NASA Facts Vol. II, No. 3
4D2 NASA Facts Vol. II, No. 5

4D3 NASA Fact Sheet—Vehicle Assembly Building
4D4 NASA Space Facts—The Birth of Rocketry
4D5 NASA How It Worked, The First Liquid Fuel Rocket
4D6 NASA Space Facts—Basic Concept of Rocket Propulsion
4D7 NASA Fact Sheet—Crawler/Transporter
4F1 Is The Carnot Cell Obsolescent?, Pratt and Whitney Corporation, West Palm Beach, Florida
4F2 Atomic Fuel, Division of Technical Information, U.S. Atomic Energy Commission, Oak Ridge, Tennessee, 1963
4F3 Nuclear Propulsion For Rockets, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 1965
4F4 Nuclear Power, U.S. Atomic Energy Commission, Oak Ridge, Tennessee, 1962
4F5 Model Rocket Supply Catalog, Estes Industries, Inc., Penrose, Colorado
4F6 The Story of Power, General Motors Corporation, Detroit, Michigan, 1955

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†NASA Facts available free from NASA. Write NASA Headquarters, Code FAD–1, Washington, D. C. 20546.

section 2

UNIT 5—GRAPHIC ARTS

INTRODUCTION

Thirty-five publications per hour are funneled into NASA. Over 200,000 scientific and technological documents have been processed by computerizing them so they may be stored and then quickly retrieved and used. Photographs may also be computerized, stored, and retrieved. This cataloging, storing, and retrieving by computer becomes more significant when one realizes that, if a chemist read steadily for one year, he would be nine years behind in the material produced during that year just in his own field.

The huge store of data developed through research and experimentation can only be preserved for the future and present use by the graphic arts processes; without these processes, the space age as well as our present day culture would be impossible.

Photography has become an essential tool in the development, firing, and testing of spacecraft. Fig. 5–1. Markings and patterns are painted on the missile so that engineers studying the photographs of the missile during launch and flight can detect even the minutest deviation from the predicted results. Motion pictures of the launch are taken at many different speeds ranging from 2 frames per second to 2,000 frames per second.

The importance of communications has been recognized in all phases of the space industry. Graphic arts machines and processes play a leading role in this communication.

LEARNING UNITS

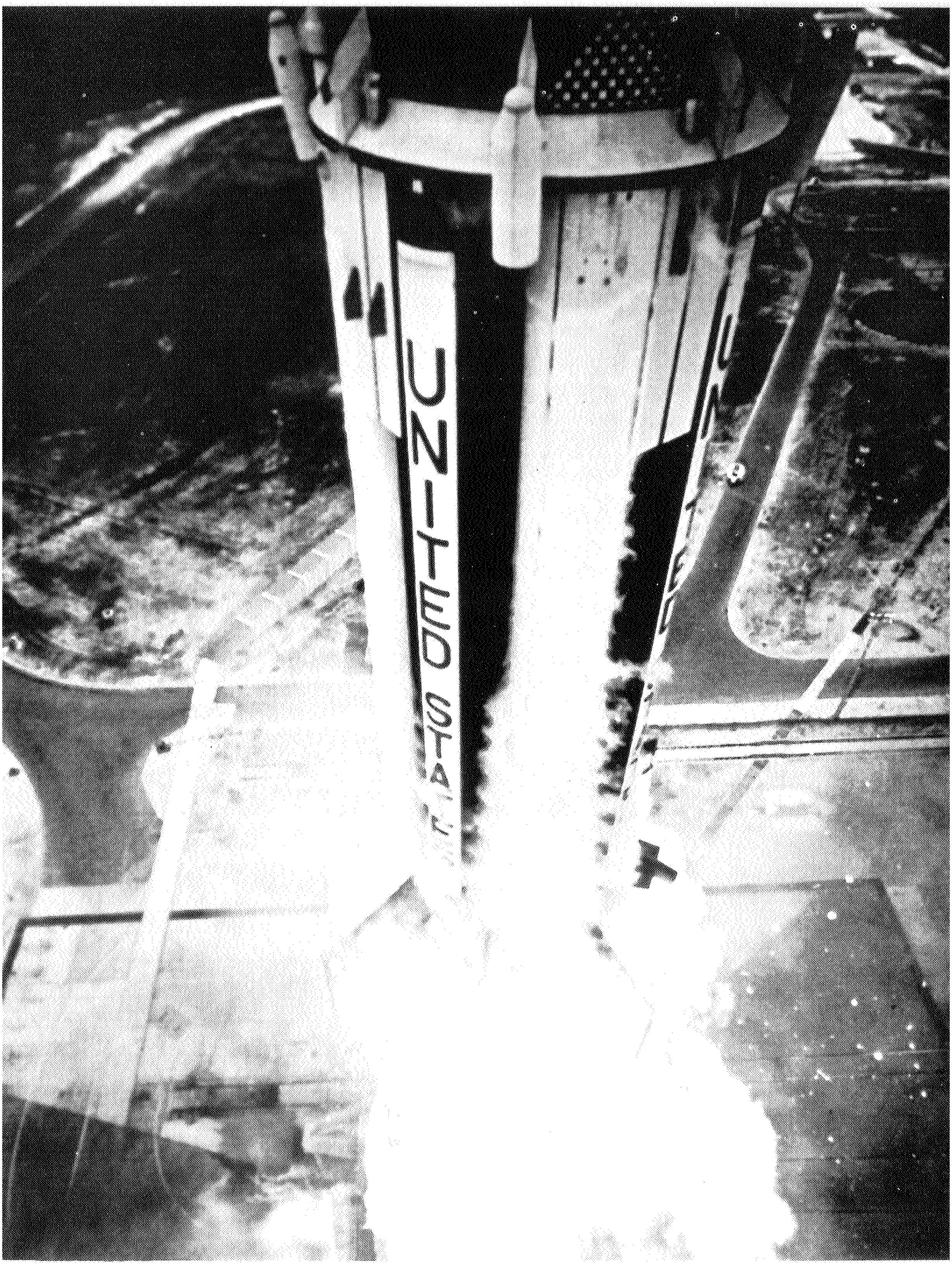
AEROSPACE APPLICATIONS

CAMERAS

Cameras mounted on the space vehicle and on the launch gantry are used to record every phase of the launch operation. Some are trained on mechanical devices, some on instruments and gauges, and some on the astronauts. Fig. 5–2. In many instances, the picture needed requires that the camera be mounted in an area of intense heat. Cameras mounted in flame areas are shielded from the heat and force by housing them in steel boxes with quartz to protect the lenses.

When cameras are mounted on those stages of the vehicle to be jettisoned, they are equipped with separation devices and flotation

Fig. 5–1. Cameras accurately record the details of rocket launching operations.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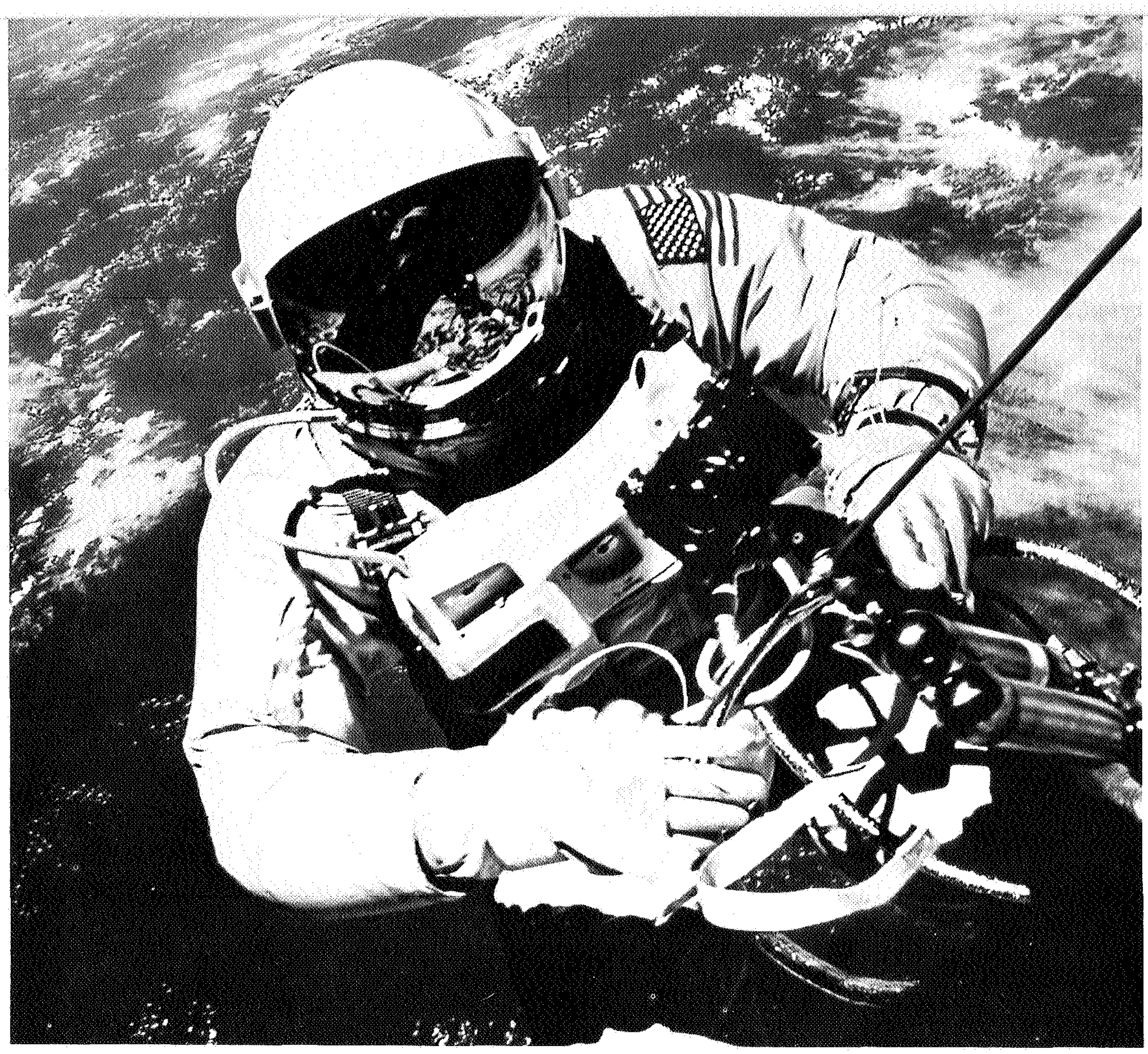

Fig. 5–2. Photograph of astronaut White's "walk in space."

material. One such camera was recovered after twenty-six days in the water, and the pictures were excellent.

Camera equipment on unmanned capsules convert pictures into electrical signals to be transmitted to earth where they are reconstructed. Cameras located in danger areas are remotely operated during launch. There are some permanent remote camera stations at launch sites, but many stations are mobile.

Special devices permit dual filming techniques. One such unit is shown in Fig. 5–3. (5C1)*

Earth-based cameras also photograph Explorer satellite signals for geodetic research. (5D1)

LENSES

The unusual demand on space photography necessitates the use of every conceivable type of lens. Research into lenses for space use should also result in improved commercial and personal equipment.

*See page 9 for Reference Code.

LEARNING UNITS **AEROSPACE APPLICATIONS**

Pictures of engine nozzles and propellant flames are taken through light-bending tubes so the camera may be mounted away from the intense heat. These tubes are fibre optics and are made of a large number of finely drawn strands of glass bound in a flexible steel tube. The light or image follows the bend of the tube.

FILMS

Space industry photography demands results heretofore not possible. Research into equipment and materials has resulted in many developments which are beneficial to commercial photography. One of these is a low-light, high-speed color film.

Iodine-quartz lamps are used to light critical areas during launches.

PRINTING

An electro-mechanical brailler has been developed to transpose pictures to braille.

ENLARGING

Schematic layouts of circuitry used in electronic equipment are reduced in size through the printing process. These circuits are then "screened" using metallic electrical conductors in the form of paint. This eliminates wiring and allows miniaturization of the circuit because soldered or mechanical connections are not needed.

Beam Splitter Used in Dual Filming Technique

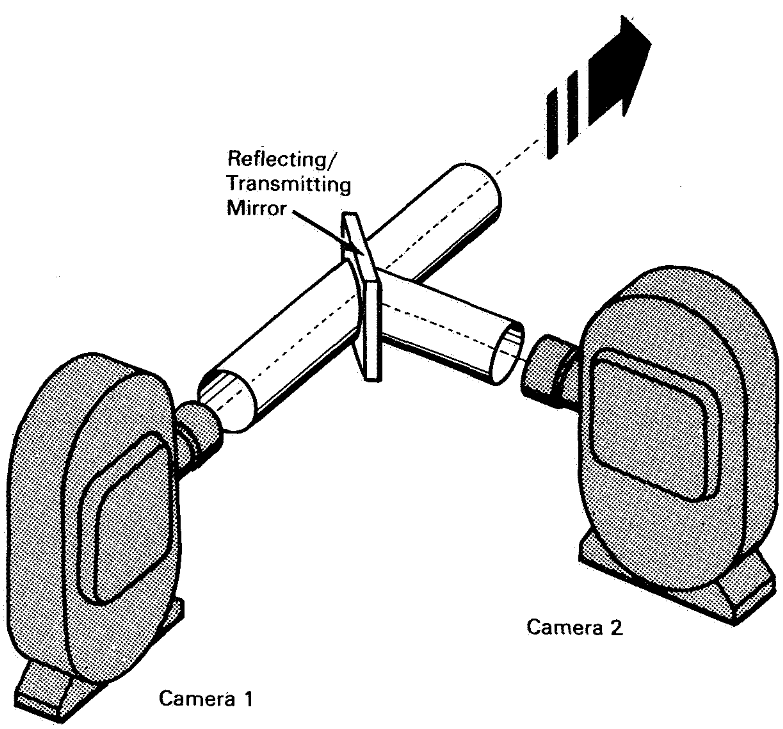

Fig. 5–3.

LEARNING UNITS — AEROSPACE APPLICATIONS

MOTION PICTURES

Motion picture cameras with a wide variety of lenses and speeds have substantially helped space engineers to locate malfunctions. These speeds range from 2 frames per second to 2,000 frames per second. A motion picture of a missile during launch taken at 400 frames per second shows every detail of the surface of the vehicle. The slightest rotation or vibration can be seen from its onset.

SAMPLE TEACHING UNIT

GRAPHIC ARTS

LEARNING UNIT	AEROSPACE APPLICATION
Two-Way Glass Mirrors	Dual Filming Technique Fig. 5–3
<u>Properties:</u> 1. High Elastic Qualities 2. Low Impact Strength 3. Can Be Tinted 4. Good Electrical Insulator 5. Good Heat Conductor 6. Reflects an Image (one side) 7. Transparent (other side) 8. High Degree of Hardness	<u>Problem:</u> To simultaneously film an event with two cameras. Space or focus conditions prevent mounting of more than one camera. <u>Solution:</u> A two-way mirror so arranged so that two images of an object are filmed from two different positions.
<u>Typical Applications:</u> 1. Observation Media (Institutions) 2. "Peep" Holes in Doors—private homes	<u>How it is done:</u> 1. Cut a tubular tee, 45° angle, at its junction. 2. Place a two-way mirror in the cut. The reflecting side should face the shorter tubular section. 3. Using epoxy cement, fasten both parts of the tee to the mirror. <u>Reference:</u> C17 66–10072, February, 1966. *Note:* Illustration C–8

REFERENCE MATERIALS

GRAPHIC ARTS

Most of the direct applications of graphic arts to the space industry are in the field of photography. Almost no specific literature is available. NASA makes use of all standard printing techniques to produce the thousands of bulletins it distributes.

Listed below are some documents of general information on research and developments in space photography.

5C1 *NASA Tech Brief 66–10072
5C2 NASA Tech Brief 65–10086
5C3 NASA Tech Brief 65–10076
5C4 NASA Tech Brief 65–10071
5C5 NASA Tech Brief 65–10252
5C6 NASA Tech Brief 65–10100
5C7 NASA Tech Brief 65–10313
5C8 NASA Tech Brief 65–10132
5C9 NASA Tech Brief 65–10339
5C10 NASA Tech Brief 65–10373
5C11 NASA Tech Brief 65–10253
5C12 NASA Tech Brief 66–10010
5C13 NASA Tech Brief 66–10016
5C14 NASA Tech Brief 65–10050
5C15 NASA Tech Brief 65–10020
5C16 NASA Tech Brief 66–10095
5D1 †NASA Facts Vol. III, No. 4

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section 2

UNIT 6—PLASTICS

INTRODUCTION

Figure 6–1 shows the three sections of the Apollo spacecraft which have been designed to land our astronauts on the surface of the moon. The Apollo command module, in which all three astronauts actually ride during the lunar voyage, is the only part of this spacecraft which makes the entire trip to the moon and back. The illustration shows the astronauts entering the LM (Lunar Module) from the command module in preparation for their descent to the moon's surface.

Fig. 6–1.

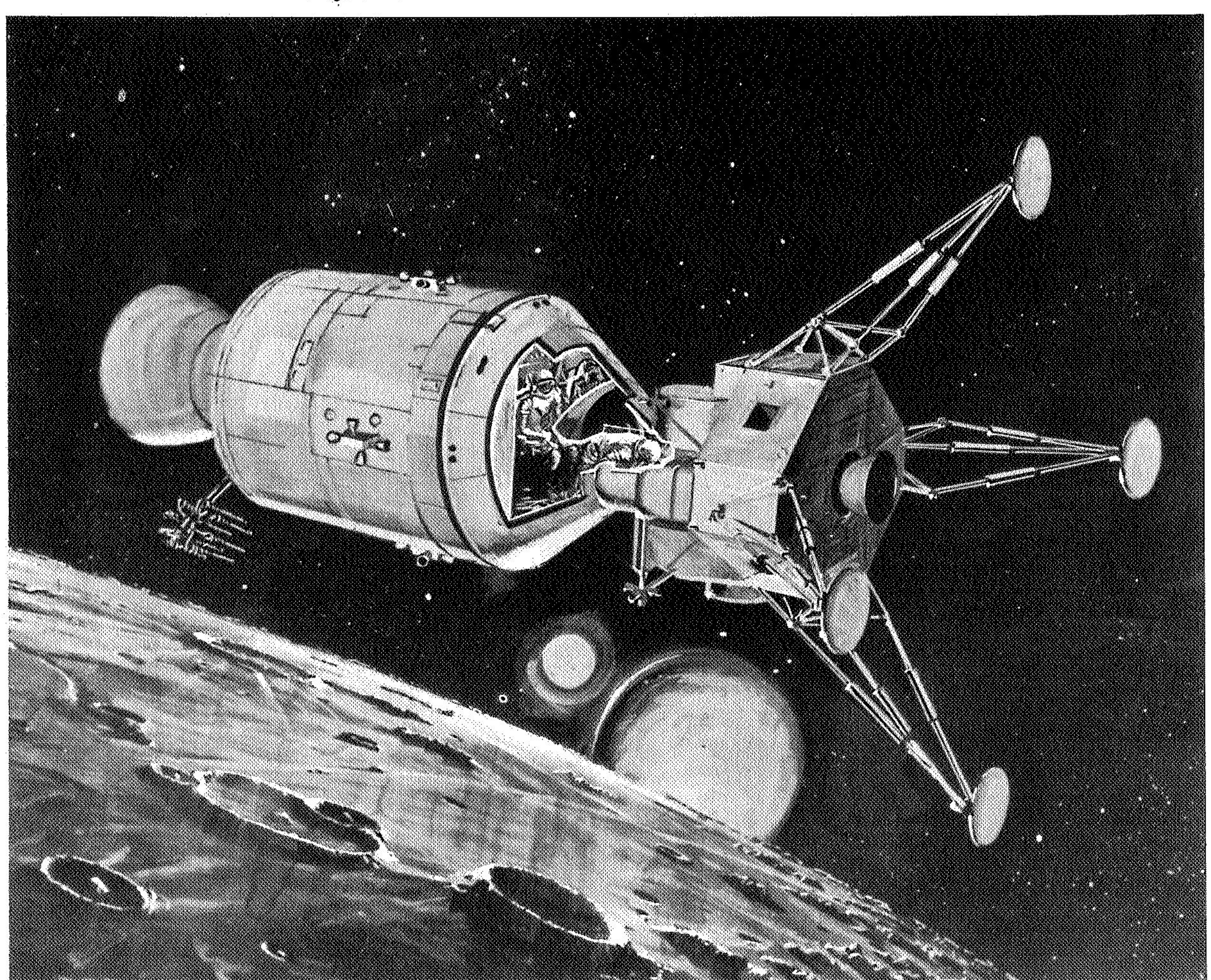


Fig. 6–2. Installing the honeycomb matrix on the blunt aft section of the command module.

The material used as a heat shield for the command module must withstand temperatures in deep space colder than 200 degrees below zero and then survive the intense heat of re-entry when the shock and friction caused by the craft slamming into the earth's atmosphere will send temperatures across the surface of the command module soaring as high as 5000° F. In addition, since the weight of the command module must be kept to a minimum, this material must be of the lowest density possible. Fig. 6–2.

The material selected to do this job is a phenolic epoxy resin—a plastic. In addition to this plastic itself, the resin is held in place on the surface of the command module by a honeycomb matrix of fiberglas—a combination plastic ceramic material. Thus, we see how the plastics are used in space technology in a most important location. Without the heat shield, it might not be possible to put a man on the moon in this decade.

LEARNING UNITS	AEROSPACE APPLICATIONS
MATERIALS (CLASSIFICATION)	Lighting diffusers
Thermoplastics	Electrical insulators
Acrylics—Plexiglass,	Safety helmets
Lucite	
Cellulosics—Celluloid	Pipes (6C14)*
Fluorocarbons—Teflon	Steering wheels
Polyamids—Nylon	Telephone headsets
Polyolefins—Polyethylene	Flashlights
Styrenes—Styrofoam	Printed circuit boards
Vinyls—Saran	Liquid storage tanks Clothing and gear insulation Packing Cable insulation Plastic components in computers Films and tapes Parachutes Liners for food cartons Gears, bearings, cams, and pulleys Bags for body wastes Final assembly building coated with vinyl Corrugated fiberglas used extensively on Cape installations Flotation collars to float spacecraft (6C11)
THERMOSETS	
Urea and Melemine—Melmac	Dishes, gaskets, bearings, and surface lamination
Caseins	Protective covering for wire, cables, and castings
Epoxies	
Phenolics—Bakelite	Electrical conduits
Polyesters—Fiberglas	Filler, linings in tanks
Silicones	Coating on heat shields
Urethanes	Insulation on motors, generators, and coils
SYNTHETICS	Electrical appliances Pyroceran-heat shield Cements for dissimilar materials Phenolic coating on dissimilar materials prevents electrolysis
URETHANE	
Properties	Polyurethane foam lines astronauts' helmets to protect against shock and reduce noise level.

See page 9 for Reference Code.

LEARNING UNITS	AEROSPACE APPLICATIONS
(Light in Weight) (Compressive) (Sound and Vibration Absorption Is Outstanding (Excellent Electrical Properties) (Thermoset and Heat Resistant) (Good Chemical Resistance) (Resistant to Rot and Vermin)	Exceptional resilience plus ability to bond makes flexible foams useful as foam liners. A 1½ inch thick rigid piece is cut to helmet size and bonded. Fig. 6–3.
Typical Applications (Cushioning Materials) (Mattresses) (Packaging)	Suggested experiments. Ask a football coach to permit you to line a helmet with polyurethane during practice and keep a record of the player's reactions. Place a piece of polyurethane foam 3 x 3 x ¼ trimmed to fit in a baseball glove and practice catching with it. Does it absorb shock? (6A1, p. 53)
CUTTING Shearing Sawing Drilling Tapping and Threading	Same processes are done in space technology as in other plastic applications. The difference being that the product will be utilized for space exploration. An example is: Tapping and threading of plugs in heat shield where defects have been discovered—covering for fasteners.
FORMING Molding Compression Injection Extrusion Blow Calendering Cold Molding Lamination	Parts for computers, knobs, switches, etc., are molded by various processes. (6C12) Laminates are used in instrument panels, computer mounts, and sides for gears, electrical panels, and shields.
THERMOFORMING Vacuum Forming Blow Forming	Small turrets of acrylic plastics are either vacuum or blow formed.
CASTING Simple Casting Dip Casting Slush Casting Rotational Casting	
REINFORCING Hand Layup Spray Up Matched Molding Premix Molding Vacuum Bag Molding	Thermal insulation blankets are sprayed up.

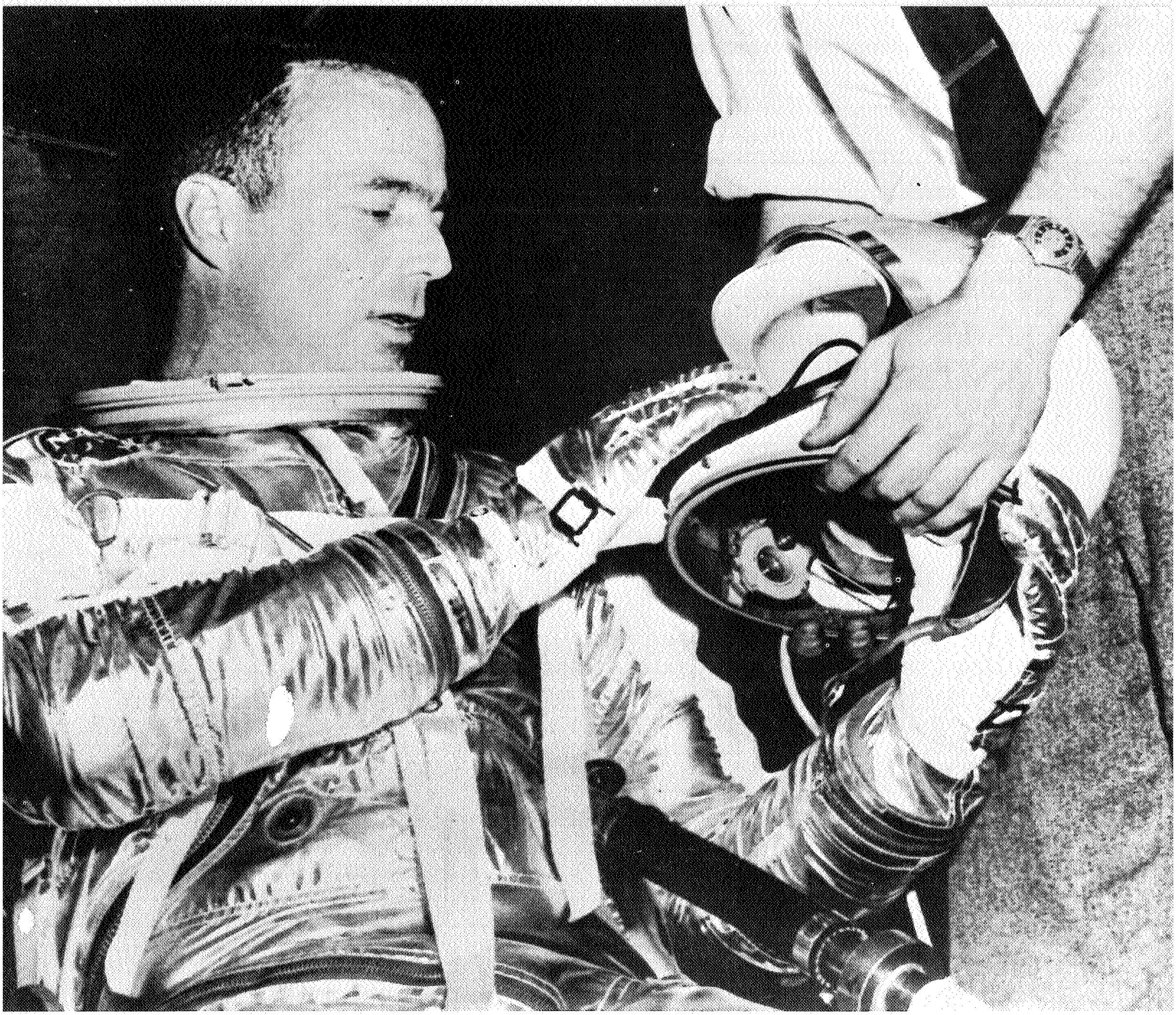


Fig. 6–3. *FOAM-LINED HELMETS protect U. S. astronauts against impact and noise when space craft are sent aloft on the man-in-space attempts. The 4½ pound, hard fiber glass helmets incorporate a 1½-inch thick layer of Nopcofoam, a rigid polyurethane foam produced by Nopco Chemical Company, North Arlington, N. J., which gives slowly under impact or shock to protect and cushion the astronaut's head during launch acceleration and re-entry deceleration. Nopco's foam, in a similar formulation, also is being used in the special contour couches made for each astronaut. Made by B. F. Goodrich, and lined by Protection, Inc., the helmet also absorbs as much as 20 decibels of sound, dropping the 115–db outside-the-helmet level to 95 db inside—well below the threshold of the level which can cause pain. Nopcofoam was selected by Protection, Inc., for its impact dissipating ability, its ease of forming into liners, and the low cost of tooling required for a limited number of liners. The foam has a load-compression curve particularly suited to the dissipation of high impact energy in the process of crushing. It successfully spreads the force over a relatively large area to take advantage of the human head's surprisingly high tolerance to distributed forces. Here, astronaut Malcolm S. Carpenter is ready to put on his custom-fitted helmet.*

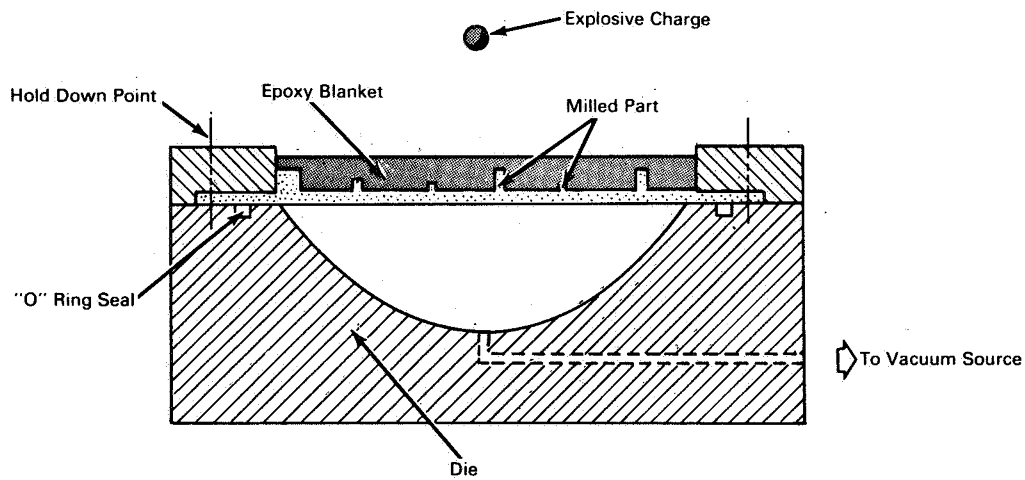
LEARNING UNITS	AEROSPACE APPLICATIONS
FOAMING Physical Foaming Chemical Foaming	Insulation on umbilical tower is sprayed, permitted to foam and harden, and is then a protective cover against corrosion. Insulating partitions are filled with chemically foamed plastic.
FASTENING Adhesive (Epoxy Resin Based) (Contact Bond) Cohesive (Solvent) (Thermalweld) Mechanical Linkage (Mechanical Fasteners) (Swaging)	All bondings of an adhesive nature are epoxy bonds, such as the heat shield on the Apollo command module. (6C13) Screws, bolts, self-tapping devices are all used in securing plastic laminates as is epoxy cement. Epoxy insulation is used in explosive forming for protection of fragile machined parts. (6C10)
FINISHING Smoothing (Cutting) (Filing) (Scraping) (Sanding) (Buffing) (Tumbling)	As is true of other operations, these cutting ones are duplicated in space technology wherever plastic materials are used.
SAFETY	Safety is of uppermost importance in space technology. For example, the driver of the crawler/transporter, which has a top speed of 1 m.p.h., wears a safety belt. Hard hats made of formed plastic are used everywhere. Correct tool usage is stressed.

LEARNING UNITS	AEROSPACE APPLICATIONS
Typical Industrial Arts Program Epoxys Properties: 1. High Tensile Strength 2. Compressive 3. High Impact Strength 4. Can Be Reinforced With Fiberglas 5. Adheres to Any Type of Surface 6. Less Shrinkage Than Most Thermosets 7. Cures at Room Temperatures 8. Excellent Electrical Resistance 9. Somewhat Heat Resistant 10. Chemically Inert Typical Applications: 1. Autobody Repair 2. China and Ceramics Repair 3. Industrial Fittings and Jigs Application: 1. Show pictures of typical application as a do-it-yourself. 2. Join pottery or ceramics with epoxy cement. Reference: 6A1	"Epoxy Blanket Protects Milled Part During Explosive Forming." Fig. 6–4a and 4b. Problem: To use explosive forming for large structural parts leaving machined sections (ribs) without damage to protruding members. Solution: An epoxy blanket uniformly covering the entire exposed section, filling all voids and machined areas. It supports rib sections and protects the entire part from the energy of the charge during forming. How it is done: 1. Coat part with a separator, such as a commercial wax or a silicone spray. 2. Spray or pour over the milled section a two-part, room temperature curing epoxy solution. Cover to a suitable thickness to protect all surfaces. 3. Use conventional explosive forming techniques and form part to the desired shape. 4. Remove the protective blanket. It is not harmed by the charge since it is resilient. It can be removed without damage and can be used over and over again. It is inexpensive and can be discarded when the forming is completed. References: 6C10 6C11 6A6

January 1966 Brief 66-10029

NASA TECH BRIEF

Epoxy Blanket Protects Milled Part During Explosive Forming



The problem:

To use explosive forming for large and complex structural parts having various chemically milled or machined sections, without causing damage to protruding members. Control of the energy released by the explosive charge is extremely difficult when the specimen or part is not homogeneous in size and configuration.

The solution:

An epoxy blanket that uniformly covers the entire exposed surface of the part and fills all voids and machined areas. This supports rib sections and uniformly protects the entire part from the energy of the charge during forming.

How it's done:

The part is first treated with a commercial wax, silicon spray, or fluorocarbon coating that will prevent the epoxy blanket from adhering to it. A two-component, room-temperature curing casting liquid is poured over the milled part set in a framelike fixture with side walls to the height of desired blanket thickness. The casting material consists of a medium viscosity hardener in proportions of 100 parts of resin to 27 parts of hardener by weight. This material cures rapidly in large masses to a tough, resilient product that is resistant to abrasion, chemicals, solvents, and high impact loads.

Following application of the epoxy blanket, standard explosive forming procedures, employing conventional dies, hold-down fixtures and vacuum techniques, are used to achieve the desired part configuration. After forming, the part is removed from the die and the epoxy blanket is readily peeled from its surface.

Fig. 6–4a.

Notes:

1. Due to its resilient characteristic after hardening, the epoxy blanket can be used for successive forming shots on the same part. It is discarded when forming is completed.
2. This casting system hardens in 10 to 15 minutes, making it attractive for a volume production operation.
3. A related innovation is described in NASA Tech Brief B65-10170, June 1965.
5. Inquiries may also be directed to:
   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama, 35812
   Reference: B66-10029

Patent status:

No patent action is contemplated by NASA.

Source: North American Aviation, Inc.
under contract to
Marshall Space Flight Center
(M-FS-307)

Fig. 6–4b.

REFERENCE MATERIALS
PLASTICS

6A1 Cope, Dwight W. and Conaway, John C. Plastics. Homewood, Illinois: Goodheart-Willcox Co., 1966.

6A2 Edwards, Lauton. Industrial Arts Plastics. Peoria, Illinois: Chas. A. Bennett Co., Inc., 1964.

6A3 Gerbracht, Carl and Robinson, Frank E. Understanding America's Industries. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1962.

6A4 Lappin, Alvin R. Plastics Projects and Techniques. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1965.

6A5 Swanson, Robert S. Plastics Technology. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1965.

6B1 NASA SP–5015 Conference on New Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

6C1 *NASA Tech Brief 66–10143

6C2 NASA Tech Brief 66–10070

6C3 NASA Tech Brief 66–10053

6C4 NASA Tech Brief 66–10041

6C5 NASA Tech Brief 66–10024

6C6 NASA Tech Brief 66–10079

6C7 NASA Tech Brief 66–10103

6C8 NASA Tech Brief 66–10072

6C9 NASA Tech Brief 66–10012

6C10 NASA Tech Brief 66–10029

6C11 NASA Tech Brief 66–10137

6C12 NASA Tech Brief 65–10177

6C13 NASA Tech Brief 65–10367

6C14 NASA Tech Brief 65–10344

6D1 †NASA Facts Vol. III, No. 1

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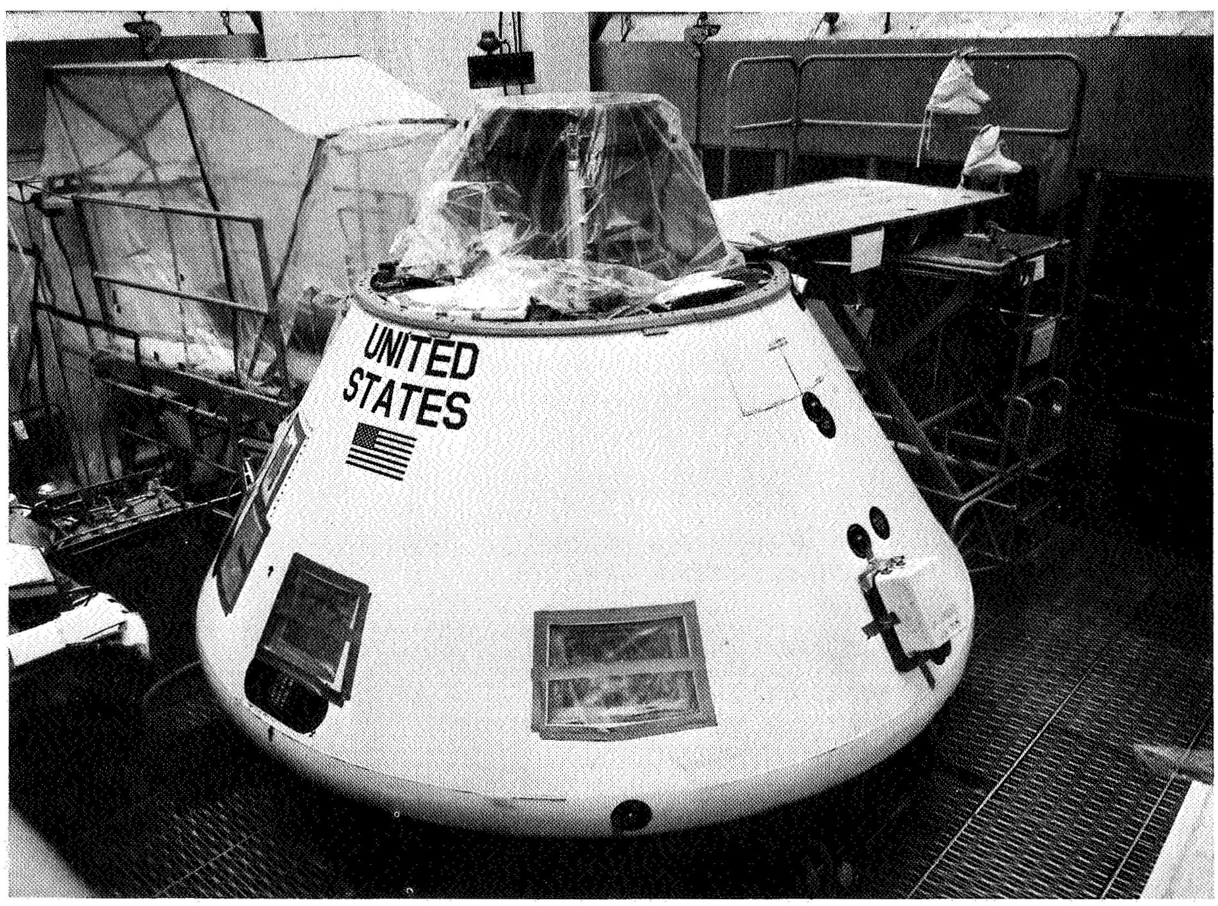
section 2

UNIT 7—CERAMICS

INTRODUCTION

If the plastics industry is important to the Apollo project, which is aimed at landing a man on the moon, ceramics has been of equal importance in arriving at the point where the Apollo command module could be designed. From the time that Alan Shepard and Gus Grissom performed their epoch making "first" flights in 1961, ceramics has had its impact on space vehicle design. Even before these most important accomplishments, however, lies the fact that, without the ceramic potential of withstanding intense heat, early experiments with rockets and rocket fuels might not have been successful.

Fig. 7–1. The Apollo command module in test stand. Its entire outher surface is a combined plastic-ceramic heat shield.



With the development of the ablative heat shield, ceramics has reached its apex in performance. The quartz ablation shield used on the nose cone of the ICBM behaves in much the same manner as the epoxy filled fiberglas honeycomb ablation shield of the Apollo command module. In both instances the ceramic materials (quartz on the ICBM—fiberglas on the ACM) because of their ability to withstand intense heat are contributing their fair share to space technology. Fig. 7–1.

In the broadest sense ceramic materials are found wherever you travel around America's Space Port. Massive use of concrete—a ceramic material—is involved in the construction of the launch pads for the Saturn tests and ultimate Apollo flights. Huge channels below these pads are lined with fire brick. These assist in carrying away the intense heat of combustion during the first moments of takeoff when there is no motion to assist in heat dissipation.

Less spectacular but of equal importance has been the development of ceramic materials capable of being bonded to thin metals to line the exhaust chambers of jet and rocket powered engines. It is quite possible that without such materials we might not have been able to conduct the experiments which have been preliminary to the space effort.

It has been from these experiments and others like them that we have received such products as pyro-ceran, which is now almost as common in America's kitchens as the Teflon-coated frying pan. In industry sintered oxide ceramics are performing with a high degree of reliability. In space technology they are thought of in terms of their high temperature refractory properties, which are useful for nose cones and rocket nozzle inserts. Unlike the usually brittle glassy materials, oxide ceramics are strong and tough. Sintered alumina is used as a check valve in liquid oxygen systems. Alumina was chosen because it could be machined spherical at room temperatures and remains that way from −450° to +1000° F. In check valve use it outlasts handened steel balls 5 to 1.

LEARNING UNITS	**AEROSPACE APPLICATIONS**
DESIGN IN CLAY	Design in space age technology. Function is more important than aesthetic appearance. Fig. 7–2. However, it usually follows that appearance and function are so often interwoven that it is impossible to divorce the two. Usually the more pleasing designs are also more functional.
MATERIALS Glass (Safety Glass) (Window Glass) (Fiberglas) (Pyrex Glass)	Safety glass portholes in spacecraft, in blockhouses, and to protect cameras on launch pads Goggles Pressure and depressure chamber portholes Lenses specially ground for cameras carried in spacecrafts

LEARNING UNITS | **AEROSPACE APPLICATIONS**

Windows in service structure
Used as a base to improve semiconductor rectifiers
Beam splitter in dual film techniques
Mirrors in sextants
Gamma ray detector is housed in glass flask
Spherical glass poppet (valve) is molded as part of no-leak seal.
Fiberglas used with aluminum to form a flexible insulation.
Fiberglas fibers reinforce thermal insulation blankets
Instrument panels
Dies for forming metal
Honeycomb in heat shield
Boats used in chemical experiments
Insulation
Liners for tanks

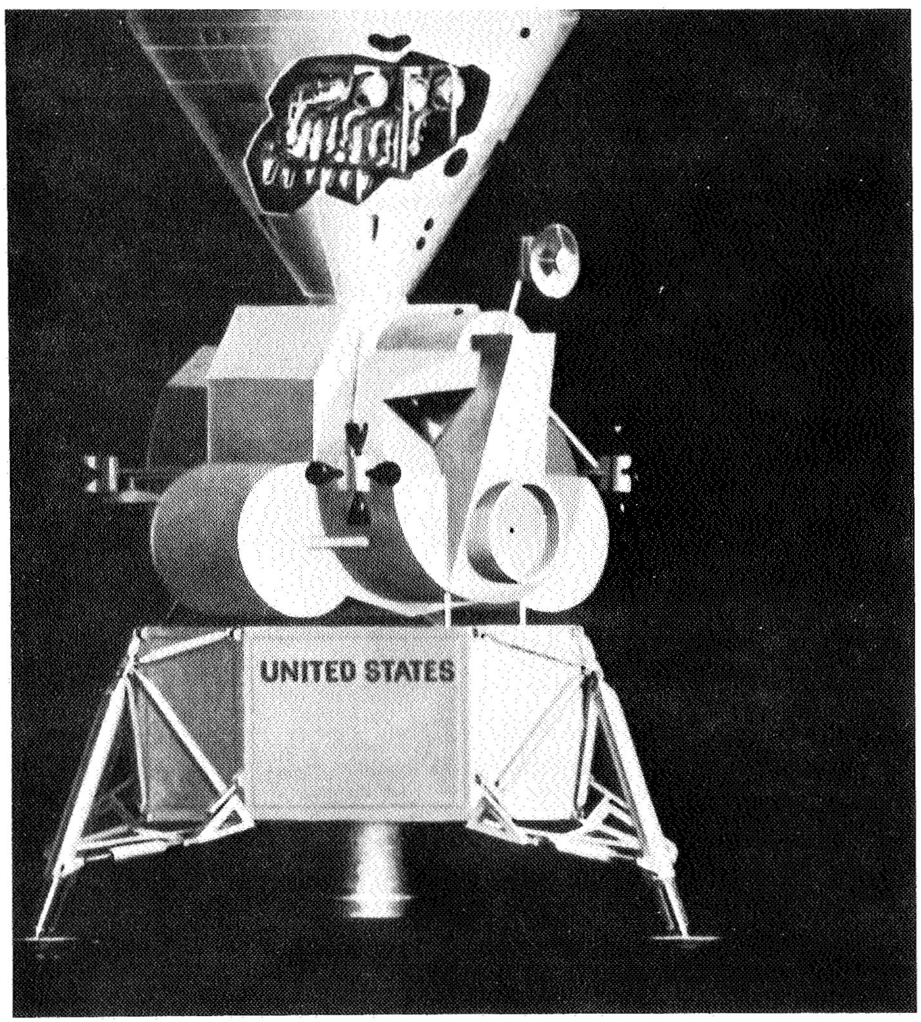


Fig. 7–2.

LEARNING UNITS	AEROSPACE APPLICATIONS
Cement (Binder)	Blockhouses
Concrete (Reinforced) (Precast—Stressed)	Launch pads withstand 5000 tons or more
Porcelain Stoneware	
Terra Cotta	Base of trackbed for movable launcher
Enamels (Glazes) (Surface Coating On Metals)	
Plaster of Paris (Modeling) (Mold Work)	Plaster form is pattern for thermal insulation blanket
New Materials (Cerro Metal [Cermet])	Ceramic to metal cable end seals used in ionization gauge. Fire brick lines flame trough under launch pad Nose cones in spacecraft Coating on metal of flame deflectors Bonded silica separates reflective insulators Fire optics—used to secure pictures from within range of rocket fire during takeoff Flexible protective coating made of silicon-nitrogen materials Ceramic bushings

PROCESSES
Pugging
Forming
Throwing
Mold Making
Jiggering
Extruding
Glazing

MACHINES
Presses
Wheels
Jigger
Pugs

SAMPLE TEACHING UNIT

CERAMICS

PLASTER OF PARIS

A. BACKGROUND

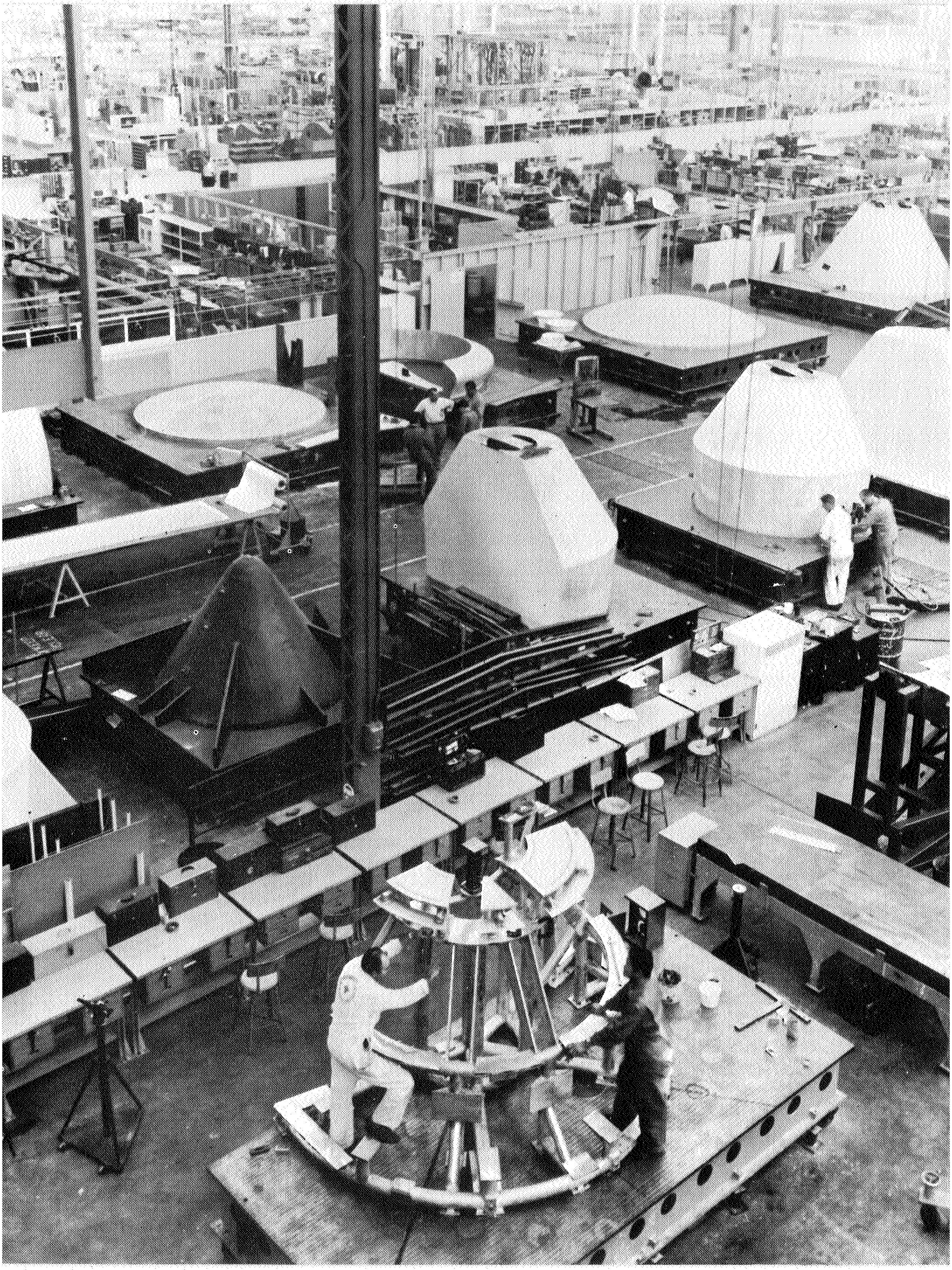
The study of the ceramics industry cannot be divorced from a study of the uses of plaster of Paris. One usually thinks of ceramics and clay as being synonymous when in reality clay is only one of the many ceramic materials. Pottery, the most common of the ceramic industries, really does not become an industry until the use of plaster of Paris is integrated with it. It is plaster of Paris which makes duplicate castings in clay possible. Duplication is the process which makes the operation an industry.

In contemporary industrial arts plaster of Paris is used very extensively for the making of molds. Its use usually ends when the mold is completed. Little manipulation of this versatile material is undertaken for no apparent reason. Industry does not end its use of plaster of Paris with the making of molds. In automotives, for instance, both clay and plastic models of new automobiles are often made. Plaster of Paris itself often becomes the end product with an inexpensive casting made from either a clay or a plastic mold. Recently, thin molds made of plastic by the vacuum forming technique have found their way on to the industrial market. Perhaps we are most familiar with items in the plastic molds to be found in handicraft work. With these molds a student may cast one or a hundred plaster products which in turn are painted and sprayed with a clear lacquer or varnish to approach the appearance of a glaze. The inexpensive prizes offered at carnivals are usually made of plaster of Paris.

In manipulating this versatile material much skill and knowledge can be developed. Since it sets up rather quickly, much preplanning and readiness is necessary before it is poured. A little experimentation with its setting qualities and the addition of small amounts of animal glue to the mixture will indicate how the setting can be retarded. A controlled experiment with varying amounts of plaster, water, and glue is an excellent research project for students. When a reasonable amount of retardation of the setting quality is obtained, you are ready for more experimentation. Fig. 7–3.

B. MOTIVATION

In space technology the use of plaster as an intermediate step in the formation of a product is an important process. For instance, in Tech Brief 66–10053 (Reference 7C2) the use of a plaster form or mock-up having the same contours as an original shape is made as an intermediate step in the fabrication of complex thermal insulation blankets. Here both ceramic and plastics are combined to fabricate the blanket. Similarly in Tech Brief B63–10481 (Reference 7C1), fused amorphous silica is formed into complex shapes by casting in plaster molds. This



ceramic product is resistant to thermal shock and exhibits good strength properties. Both of these qualities are important to specific space applications.

C. UNIT ORGANIZATION

In order to develop a degree of skill and an understanding of the problems involved in using plaster for such operations as are indicated above, a simple, manipulative process long familiar to the ceramicist but often neglected in industrial arts ceramics may be utilized. The materials may be easily fabricated, and once the knowledge of the setting properties of the plaster is determined, the student is ready to proceed. Incidentally, mold makers in the ceramics industry are some of the highest paid craftsmen. The training period is apt to be long and arduous, but the results are well worth the effort. Our outstanding sculptors are very often as adept in the manipulation of plaster of Paris as they are of clay, wood, or stone. Sculptors who cast in nonferrous metals also must be adept in the manipulation of this versatile material.

D. ACTIVITIES

The process described below is also described in greater detail in 7A1 and 7A2 in the bibliography.

1. The student first sets about constructing the necessary equipment. This consists of a small box designed to accommodate both a metal crank and a metal template.
2. The plaster is then daubed on the string which is rotated so as to receive a coat of plaster all around its circumference.
3. Continue to pile up the plaster until it contacts the template.
4. This template will shape the plaster to conform to the desired model. After the shape is roughed out, the template is cleaned, a thin finished coat of plaster is applied, and this coat is turned down using the cleaned template.
5. The finished mold is then completed. 7A1 goes on to describe how this mold is used to make the molds for casting clay vases. For our purposes this completes the activity. However, at this point it may be well to suggest that students refer to Chapters 5 and 7 in 7A1 or Unit 5 in 7A2 for additional material.

E. EVALUATION

At this point the student should have received a basic understanding of several ways in which plaster is utilized in the ceramics industry. By relating these experiences to the Tech Briefs mentioned previously, he should be able to understand more fully how plaster, clay, and fiberglas are utilized in space technology. He should be able to connect the experiences which he had in the industrial arts laboratory in manipu-

Fig. 7–3. MODELING APOLLO—Plaster master models of NASA's Apollo spacecraft are taking form at North American's Space and Information Systems Division, Downey, California. Saucer-like (rear) are early patterns for command module's heat shield.

lating plaster with those necessary to perform the intermediate steps described in the Tech Briefs. How successful he is in these endeavors can be determined by an evaluation of his finished products or by a test of the general knowledge which he has received. A culminating activity could very well be the written report of his activities tying them in to space technology. A natural follow-up activity would be to produce a number of finished products with space application as a class project or to develop a mass production project involving all three activities—plaster fabrication, clay casting, and fiberglas forming.

REFERENCE MATERIALS
CERAMICS

(Film List—See Appendix II, page 161)

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7A2 Gerbracht, Carl and Robinson, Frank E. Understanding America's Industries. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1962.

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7B1 NASA SP–5021 Index to NASA Tech Briefs, Issue No. 1, January, 1965, Clearinghouse for Scientific and Technical Information, Springfield, Virginia. $1.00

7B2 NASA SP–5021 (01) Index to NASA Tech Briefs, Issue No. 2, August, 1965, Clearinghouse for Scientific and Technical Information, Springfield, Virginia. $1.00

7B3 NASA SP–40 Conference on Space-Age Planning, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $2.00

7C1 *NASA Tech Brief 63–10481
7C2 NASA Tech Brief 66–10053

Supplemental Tech Briefs not directly related to this unit but showing ceramics involved in space technology are as follows:

7C3 NASA Tech Brief 64–10116
7C4 NASA Tech Brief 63–10562
7C5 NASA Tech Brief 64–10099
7C6 NASA Tech Brief 66–10010
7C7 NASA Tech Brief 66–10143
7C8 NASA Tech Brief 66–10024
7C9 NASA Tech Brief 66–10095
7C10 NASA Tech Brief 66–10086
7C11 NASA Tech Brief 66–10046
7C12 NASA Tech Brief 66–10070
7C13 NASA Tech Brief 66–10027
7C14 NASA Tech Brief 66–10041
7C15 NASA Tech Brief 66–10079
7C16 NASA Tech Brief 66–10103
7C17 NASA Tech Brief 66–10072
7C18 NASA Tech Brief 66–10012
7C19 NASA Tech Brief 65–10210
7C20 NASA Tech Brief 65–10063
7C21 NASA Tech Brief 65–10357
7C22 NASA Tech Brief 65–10481
7C23 NASA Tech Brief 66–10127
7D1 †NASA FACTS Volume III, No. 1
7D2 NASA FACTS Volume II, No. 8

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section 2

UNIT 8—WOODS

INTRODUCTION

A trip through a space facility, such as the John F. Kennedy Space Center, impresses one very obvious fact on the mind of an industrial arts teacher. Material usage has been refined to an extreme degree. Everywhere he goes he sees industrial materials being used in much the same manner as he sees them being used in everyday life. Plastics are much in evidence. Ceramic materials, particularly cement and concrete, are seen at every turn. Electricity-electronics is the backbone of the telemetry system, and its functions are inherent in all tracking systems, blast-off systems, computer control, and communications. The actual construction of the Center features an inordinate amount of metals, from the VAB (Vehicle Assembly Building) and the crawler/transporter to the mobile launchers and the launch site itself. In fact,

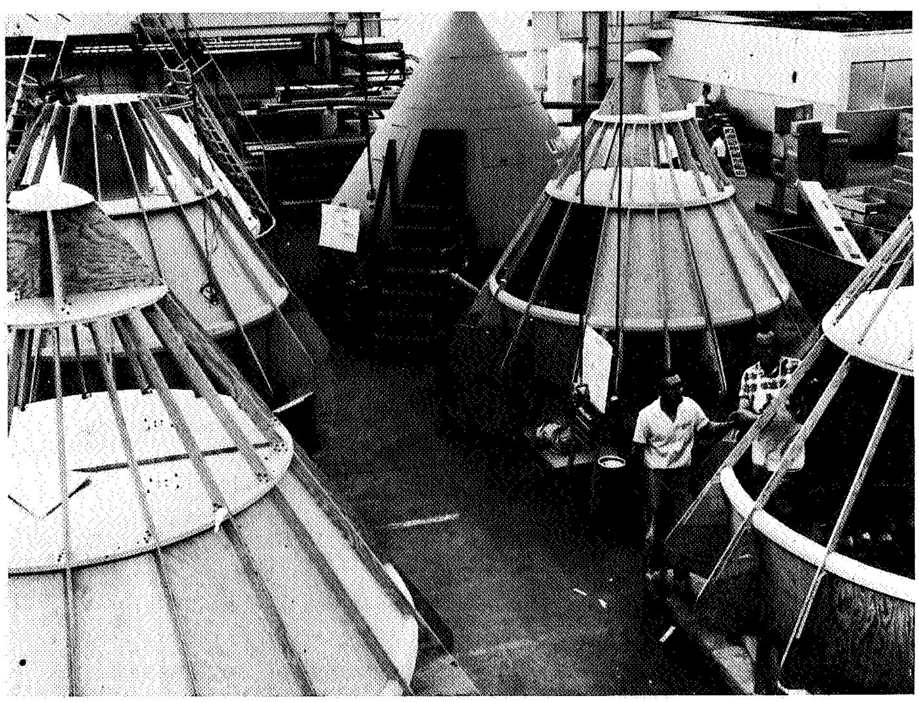


Fig. 8–1. Wooden Apollo command modules under construction in the early phases of developing flight models. This 12-foot tall command module, weighing five tons, will house three astronauts.

every material commonly featured in contemporary industrial arts is represented in space technology except one. This exception is woods. Except for the usual construction timbers, crating ladders (although most of these are metal), and concrete forms, typical woodworking manipulation is almost totally lacking.

At first thought, one assumes this to be an obvious fact. Since not one piece of wood equipment will go to the moon with the possible exception of a wood handle on a geological specimen pick or a balsa cover on instruments, it would seem that woodworking was being phased out completely. Many industrial arts instructors are in accord with this implication. For better than half a century woodworking has been the backbone of industrial arts. It has been exploited almost to the exclusion of other industrial processes. According to the most recent surveys, it is still being carried on in the majority of the Nation's industrial arts laboratories, but it is being de-emphasized wherever revision of the program is under way.

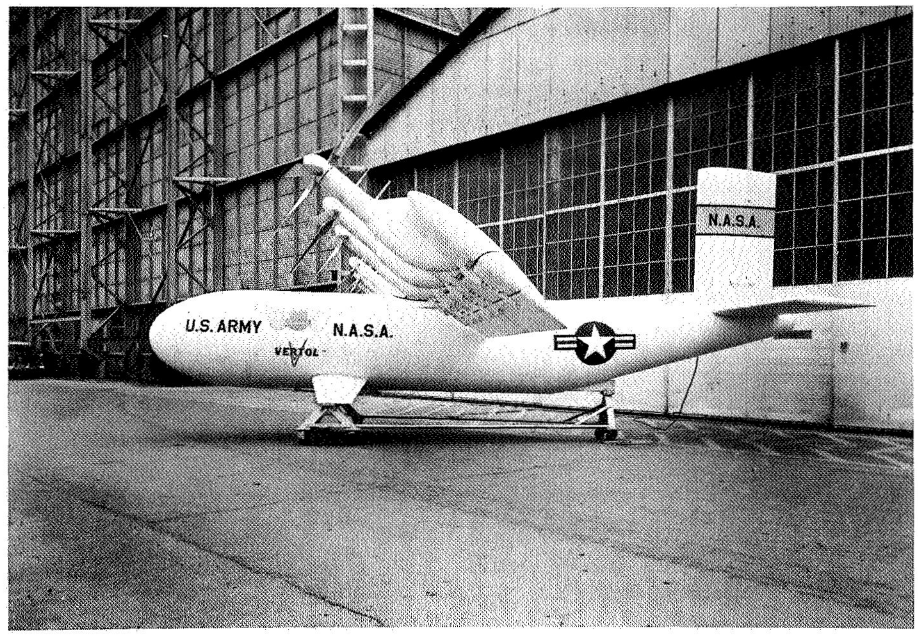


Fig. 8–2.

This would seem to be in keeping with space technology judging by the preponderance of other materials being utilized. However, on close investigation one discovers that woodworking is still the "backbone" of the space industry. Fig. 8–1. Kennedy Space Center is the Country's space port. It is here that space technology pays off. The space probes and moon missions depart from here. Behind these final stages are literally thousands of man-hours of preparation. Still further behind these takeoff preparations are millions of man-hours of experimentation, research and development, and fundamental material manipulation. Primary in all these experiences is the involvement of wood technology.

Notice the VTOL (Vertical Take-Off and Land) model in Fig. 8–2. Prototype models such as these are most often made of wood at some

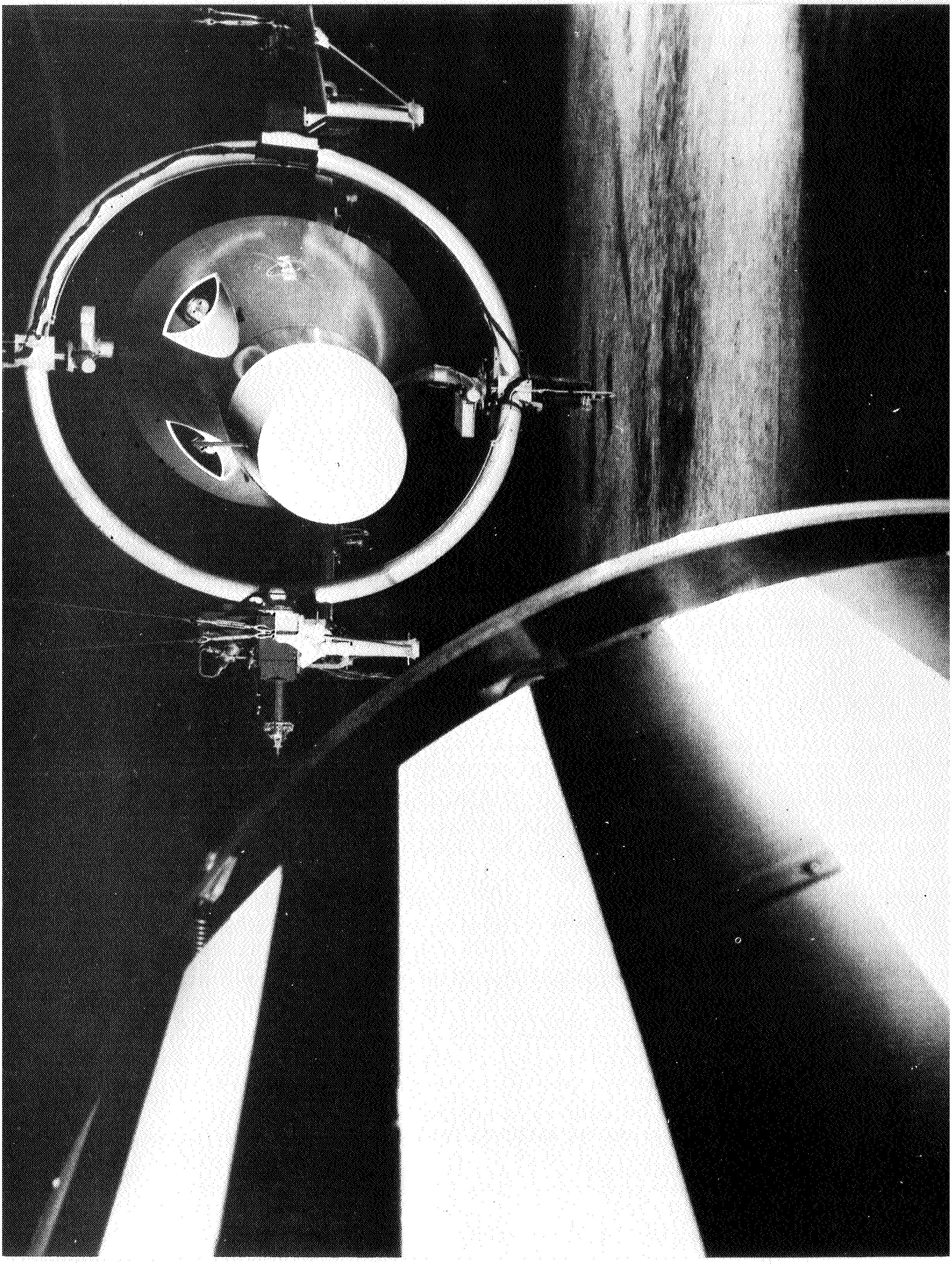
stage of their development. While models such as these are not directly considered to be space vehicles, Figure 8–1 on the cover page shows mock-ups of Apollo command modules which are used for rehearsing hundreds of preliminary operations. Mock-ups such as these and similar ones as the space rendezvous simulator as seen in Fig. 8–3 are often constructed primarily of wood, metal, and plastics.

To prepare astronauts for the lunar journey, NASA has constructed a number of simulators. In the simulators are embodied the ideas, skills, and knowledge of an army of engineers, scientists, and other technologists.

To simulate is to assume the appearance of, without reality. This is exactly what the manned space flight simulators are designed to do. The pilots are made to feel that they are on an actual space mission. In this way also techniques and equipment are developed for reliable operation in space.

Without such models and simulators, the progress of research would be greatly hampered. The cost of such research and development would be prohibitive for even such a nation as ours if simulated conditions and equipment were not employed. In space technology, wood technology has risen to a height never experienced before. The finest wood craftsmen and the most highly developed skills in wood fabrication are found in space technology. Truly, wood and all that the wood area implies is the "backbone" of space technology.

LEARNING UNITS	**AEROSPACE APPLICATIONS**
LAYOUT AND DESIGN Basic Design Principals Working Drawings	Designs of most space probes, space vehicles, and command modules are modeled in wood. Preliminary drawings for these are similar to other woodworking drawings.
MATERIALS Wood Technology (Species) (Lumbering) Wood Products (Veneers) (Plywood) (Hardboard) (Particle board)	Most models and patterns for castings are made of mahogany. Veneers and plywood used extensively in model making. See Fig. 8–1.
PROCESSES Cutting (Sawing) (Shaping) (Molding) (Planing) (Drilling)	All regular industrial arts type processes are duplicated, often to a much more skilful degree, in space technology. These are too numerous to list at this point. It is sufficient to say that all wood processes are utilized in space work including cutting processes, forming processes, and fastening processes. It is in this last process, however, that wood technology reaches an extreme high. The development of new adhe- *Fig. 8–3.*



LEARNING UNITS	AEROSPACE APPLICATIONS
Forming (Bending) (Laminating)	sives for space work will affect this process in contemporary woodwork. The fastening of wood and glass, plastic, metal, and other materials will eventually result in a common bonding material which will simplify this process in all areas. Such bonding materials are already in use—the epoxies. "Epoxy" cement is now frequently used in fastening combinations with wood, tile, metal, etc., and will not shrink or swell during hardening and is also nonflammable. (8A1)*
	"The ideal material on the basis of performance requirements always seems to have the characteristic of being difficult in either forming, machining, or joining." (8B1) Space technology is contributing its share to the improvements of wood technology in this respect. (8C1) (8C2)
FASTENING Adhesive Gluing and Clamping	NASA has developed a calibrated clamp to facilitate pressure applications to hold materials together or to hold the work to a surface during bonding, machining, welding, and other similar operations. (8C3)
MECHANICAL LINKAGE Screws Nails Corner Braces, T Plates, Etc.	The frequent use of laminated wood in space construction activities implies the development of more skills in this process and in methods of fastening. (8C4) (8C5)
TOOL MAINTENANCE	Tool maintenance has ample application in space technology. This is as true for wood applications as it is for any process. Successful woodworking depends upon good cutting edges. The accuracy needed in model and patternmaking in space technology is dependent to a great degree on tool maintenance.
FINISHING Sanding (Cutting) Staining, Bleaching, and Coloring Filling Varnishing Shellacing Lacquers Penetrating Finishes	Constant experimentation is going on to improve finishing procedures. The knowledge and skills in finishing woodwork are fundamentals frequently applied in the construction of space projects. Many new materials and processes developed in space technology have application to woodworking. For example, the corrosion control techniques are being incorporated in wood finishing. (8C6)
SAFETY	Safety is one of the most important concerns in space activities. The development of a proper attitude and habits for safety are very important goals for space technology which can be developed in industrial arts woodworking laboratories as well as all industrial arts activities.

See page 9 for Reference Code.

SAMPLE TEACHING UNIT
WOODS

LEARNING UNITS	AEROSPACE APPLICATIONS
Typical Industrial Arts Program Gluing a Joint Procedure: 1. Test all surfaces for fit. 2. Check numbered pieces for correct relationship. 3. Adjust clamps (provide protective blocks) and make a dry run. 4. Disassemble and apply glue. 5. Apply pressure with clamps. 6. Wipe off excess glue. 7. Permit glue to cure. 8. Room temperature should be 70°. Safety: 1. No excess pressure applied to any clamp fixture. 2. Employ assistance with heavy or awkard projects. Reference: (8A1)	"Calibrated Clamp Facilitates Pressure Application" Fig. 8–4. Problem: Applying a specific clamping pressure to hold materials together or to hold work to a surface during bonding, machining, welding, and other similar operations. Solution: A spring-loaded clamp having two adjustable legs that are terminated in suction cups permitting easy attachment to a surface. How it is done: 1. Two threaded bolts connected to the crossbar are fitted with suction cups. 2. The pressure plate is attached to the spring-loaded rod passing through a hole in the center of the crossbar. 3. Suction cups are placed on a supporting surface and fastened, if necessary, with a nonhardening adhesive. 4. Screw bolts are adjusted to apply the desired pressure to the pressure plate. a. The spring-loaded rod may be provided with calibrated markings to indicate the applied pressure. Reference: (8C3)

February 1966 Brief 66-10059

NASA TECH BRIEF

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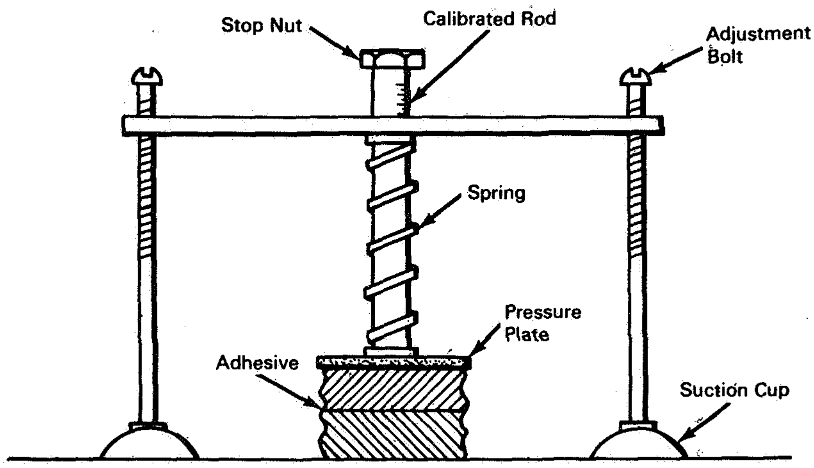
Calibrated Clamp Facilitates Pressure Application



The problem:

Applying a specific clamping pressure to hold materials together or to hold work to a surface during bonding, machining, welding, and other similar operations.

The solution:

A spring-loaded clamp having two adjustable legs that are terminated in suction cups, permitting easy attachment to a surface.

How it's done:

The two threaded bolts connected to the crossbar are fitted with suction cups in a swivel connection, facilitating attachment to a curved surface. The pressure plate is attached to the spring-loaded rod passing through a hole in the center of the crossbar.

When the device is used to clamp materials together, the suction cups are placed on a supporting surface and fastened, if necessary, with a nonhardening adhesive. The screw bolts are then adjusted to apply the desired pressure to the pressure plate. The spring-loaded rod may be provided with calibrated markings to indicate the applied pressure.

Note:

Inquiries concerning this invention may be directed to:

Technology Utilization Officer
Manned Spacecraft Center
P.O. Box 1537
Houston, Texas, 77001
Reference: B66-10059

Fig. 8-4.

REFERENCE MATERIALS

WOODS

(Film List—See Appendix II, page 161)

8A1 Feirer, John L. Woodworking for Industry. Peoria, Illinois: Chas. A. Bennett Co., Inc., 1963.

8A2 Feirer, John L. Industrial Arts Woodworking. Peoria, Illinois: Chas. A. Bennett Co., Inc., 1965.

8A3 Gerbracht, Carl and Robinson, Frank E. Understanding America's Industries. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1962.

8A4 Groneman, Chris H. and Glazener, Everett R. Technical Woodworking. New York: McGraw-Hill Book Co., Inc., 1966.

8A5 Hammond, James J., Donnelly, Edward T., Harrod, Walter, and Rayner, Norman. Woodworking Technology. Bloomington, Illinois: McKnight and McKnight Publishing Co., 1961.

8B1 NASA SP–5015 Conference on New Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

8B2 NASA Project Model Spacecraft Construction, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1.00

8C1 *NASA Tech Brief 65–70004

8C2 NASA Tech Brief 64–10142

8C3 NASA Tech Brief 66–10059

8C4 NASA Tech Brief 63–10023

8C5 NASA Tech Brief 63–10292

8C6 NASA Tech Brief 65–10156

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section 3

section 3
NEWER DIRECTIONS

INTRODUCTION

In addition to the typical industrial arts programs and activities found in every state today, one can see some newer kinds of programs. Experimental classes are successfully treating such areas as the research and development of products, materials experimentation, in-depth studies of industry, science coordination, junior engineering, mass production, and others. Valuable research is also being undertaken to probe the elements or fundamental concepts of industry; to relate a detailed study of various technologies to industrial arts; and to re-establish the industrial arts position with respect to general education through the medium of technological history or highly integrative programs. Each of these far-reaching undertakings will, or are, giving new life and direction to the profession.

Aerospace education does and should have a part in these newer offerings. The purpose of this section is to explore some means of involving the space age with these newer industrial programs.

A. IN-DEPTH STUDIES OF AEROSPACE INDUSTRIES

A study of the chemical, iron, or rubber industries, to name just a few, is a fascinating and rewarding experience for both student and teacher. A typical outline for such an activity is as follows:

1. Origin and background of the industry
2. Organization
3. Products
4. Processes
5. Materials
6. Occupations
7. Trends
8. Interrelationships with aerospace activities
9. Working model of the industry (optional)

As described in Section 1, there are numerous industries related to the space program. Some of these are listed below and provide a list from which to select an industry for in-depth study.

SOME MAJOR INDUSTRIES	TOTAL EMPLOYMENT (Approximate Figures for 1965)
Aircraft, missile, and spacecraft *manufacturing**	1,300,000
Atomic energy field	200,000
Civilian aviation	85,000
Electric power industry	430,000
Electronic manufacturing	820,000
Foundry industry	300,000
Industrial chemical industry	455,000
Iron and steel industry	625,000
Motor vehicle and equipment *manufacturing**	850,000
Petroleum and natural gas production and processing	440,000
Pulp, paper, and allied products industries	130,000
Radio and television broadcasting	100.000
Telephone industry	700.000

**Note that the employment listed is in manufacturing only.*

Studies of industries require a concentrated research effort by students in order to prepare a useful and meaningful report. A variety of research activities is recommended as indicated in the list below:

1. Library research
2. Movies and other audio-visual aids
3. Field trips
4. Construction of models
5. Collection of exhibit materials
6. Individual contacts with industry and industrial leaders
7. Presentations by industrial leaders
8. Bibliography

B. STUDIES OF AEROSPACE MATERIALS

The materials of industry provide an important and interesting source of industrial arts activities. Such studies rarely make up the content of an entire course; generally, they are employed as enrichment units involving small groups of students or the entire class. The new materials and new methods of using or processing old materials in the aerospace industry provide many opportunities for study. A suggested outline for materials study and experimentation is as follows:

1. Material description
2. Source of the material
3. Properties of the material
4. Aerospace applications of the material
5. Experiments
6. Industrial arts applications of the material

A sample study problem:

"Honeycomb is playing an increasingly important role in NASA's Apollo program not only as a means to provide needed strength at lowest weight but also to solve some unusual energy absorption insulation and ablation problems."

"Weight reduction and strength are the primary reason for the

choice of honeycomb over conventional materials and methods of construction. Aluminum reinforced fiberglas and stainless steel-honeycomb are widely used in the space industry."

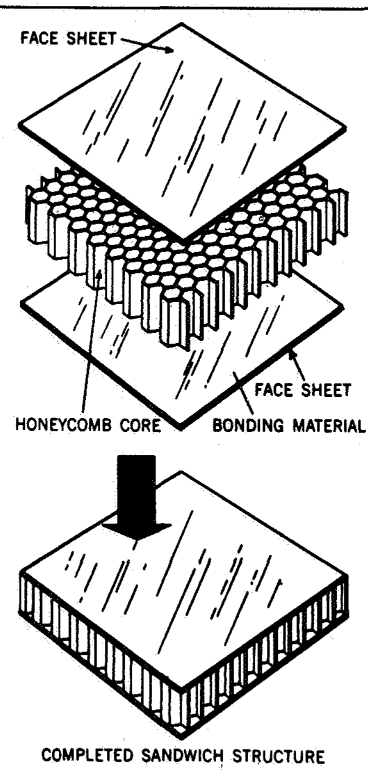
1. Material Description (See Fig. 1–1.)

For the designer, honeycomb is not an end product—it is a material form. The unusual characteristics of honeycomb are used to make new products, improve existing products, or to solve design problems. Honeycomb is a series of hexagonal cells, nested together to form panels similar in appearance to a cross-sectional slice of a beehive. Honeycomb, in its expanded form, is 90 to 99 percent open space. [It can be made of almost any expandable material.]

The basic geometry of honeycomb provides five primary characteristics. Each characteristic can be combined with the qualities inherent in the material selected. Since honeycomb can be produced from almost any material available in continuous web or roll form, the extent to which honeycomb's characteristics can be used to advantage is unlimited.

Five Basic Characteristics of Honeycomb—

1. Highest strength-to-weight ratio as a sandwich core.
2. Exposure of surface area in parallel cells.
3. High ratio of exposed surface area to total volume.
4. Variable ratio of foil area to volume.
5. Uniform crushing strength under compression.



Three elements make up a honeycomb sandwich panel: face sheets, core, adhesive.

Fig. 1–1.

2. Sources of the Material

a. Fiberglas and plastic honeycomb (phenolic epoxy resin): chemical and plastics industries.
b. Metal honeycomb: metal industries.
c. Honeycomb products: Hexcel Products, Inc., 2332 Fourth Street, Berkley, California 94710; Avco Corporation, Wilmington, Massachusetts.

3. Properties of the Material

a. *Thermal* Honeycomb is available for almost any temperature range. Heat-resistant, glass-plastic honeycomb materials display good medium temperature range (250–500° F.), strength properties and excellent thermal stability. These properties, combined with low thermal conductivity, have resulted in extensive use of honeycomb in aircraft and missile structures operating within such temperature ranges. Fabrication adhesives are also available. Hexcel has developed a proprietary solid state diffusion bonding process called ASTROWELD® for honeycomb applications.

b. *Electrical* Electrical and mechanical properties of glass-fabric reinforced plastic honeycomb have led to general incorporation of the material in both airborne and ground radome assemblies. These structures often carry high loads, demand considerable core strength, and must serve as efficient radar windows without distortion of transmission.

c. *Fatigue Resistance* Bonded metal honeycomb sandwich has replaced riveted structures in many areas of modern jet aircraft subject to high-energy sonic vibration. Stress concentration is minimized when loads are distributed evenly in this type of bonded structure, and operating life is increased by several orders of magnitude. While fatigue resistance is relative to operating conditions and design, all experience to date indicates that honeycomb structures offer resistance to fatigue loading far superior to that of alternate methods of design.

d. *Rigidity* As with fatigue resistance, the rigidity attainable through the use of honeycomb sandwich structures is dependent upon the design. However, the nature of honeycomb core in the form of a structural sandwich allows for the design of near-zero deflection structures.

Where reflective surfaces of extremely low deflection and high accuracy are required, honeycomb sandwich is a proven and widely used design approach. Applications range from mammoth ground support equipment to small, specialized reflectors for environments.

e. *Environmental* Since honeycomb core can provide the same properties as the material selected, the choice of the material alone dictates the performance of honeycomb in unusual or potentially damaging environments in structural or non-structural applications. Reinforced plastic and metallic honeycomb display the same corrosion and temperature-resistant characteristics as the basic material. Paper honeycomb impregnated with a phenolic resin is resistant to moisture and fungus.

4. Aerospace Applications

a. Apollo Spacecraft Command Module (See Fig. 1–2)
   (1) Crew compartment structural shell—aluminum honeycomb
   (2) Astronaut shock protection—aluminum honeycome cylinders
   (3) Crew compartment shock protection—aluminum honeycomb re-entry shock absorber
   (4) Heat shield—stainless steel honeycomb core, chem-milled inner and outer skins
   (5) Ablative heat shield—fiberglas honeycomb, cells filled with ablative material (phenolic epoxy resin). The entire module is covered with this ablative heat shield. The shield is designed to burn off upon re-entry and thereby carry heat away from the module and its occupants. (See Fig. 1–3)
   (6) Structural support—aluminum honeycomb sandwich panels.

5. Experiments

a. Obtain samples and test for crush strength, heat resistance fatigue, and rigidity.
b. Design furniture, recreation equipment, and small buildings.

6. Industrial Arts Applications

a. Study the uses of honeycomb in other products (doors, bookcases, etc.)
b. Build projects from honeycomb parts. (See Experiments)

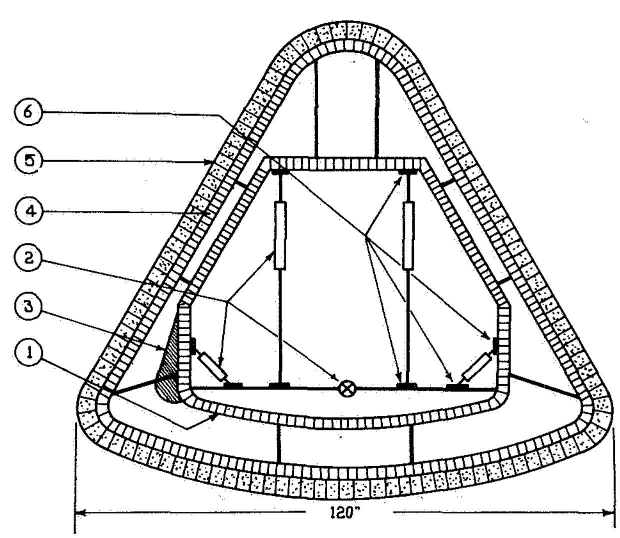


Fig. 1–2.

Fig. 1–3. Honeycomb ablative shield for the Apollo command module.

C. JUNIOR ENGINEERING (Research and Development)

Junior engineering as a rule is not designed for the pre-engineering student alone but is also for any above average student interested in exploring technology through original and creative thinking. The course gives an overview of the technological world utilizing such learning devices as knowledge sharing, conceptual approaches, brain storming, and R and D teams. Although certain aspects of occupational guidance are included, the content is valuable to the general education of any student regardless of future occupational plans.

Each student does detail work on an individual practical problem. The problems are of an exploratory nature and require individual research besides a necessary amount of mathematics, science, English, and social science. The objective is to develop creative thinking ability; allowing for individual differences is of primary concern.

The following list indicates the broad range of engineering problems. There may be either an individual or a team effort, and the structure of the problems may be modified to suit the age and ability of the student.

1. Design and construction of scale U.S. space vehicles
2. Fabrication techniques
3. Wind tunnel testing of the models
4. Static testing of the models
5. Design and construction of launch systems
6. Communication systems
7. A miniature transmitter for use as a payload
8. Tracking systems
9. Astronomy
10. Solar powered transmitters
11. Aerial photography
12. Acclerometers
13. Parachute design and construction
14. Boost-glider design
15. Nuclear reactor and dam
16. Computer design
17. Reactor cover plate
18. Satellite design
19. Space station
20. Air car design
21. Nuclear powered rocket
22. Glider design
23. Navigation problem
24. Satellite tracking station
25. Design and construct a model of a blockhouse and its related launch structures. Prepare an exhibit of this complex.
26. Construct a model of a launch service tower (or a section of it) to illustrate the structural problems involved.
27. Design fasteners to replace nuts and bolts that would possess a smooth corrosion resistant surface and would be easy to keep finished yet could be removed or tightened with simple tools.

SAMPLE JUNIOR ENGINEERING PROBLEM

1. Design and build a "no friction device" to simulate tightening a bolt in outer space.

   In outer space where forces of gravity and the resulting friction is minimal, special tools must be developed in order that the astronauts may successfully perform required experiments.
2. Determine the amount of contraction and expansion of various metals and alloys in the temperature range experienced in the various spacecraft environments.

   From many degrees above zero F. to many degrees below zero F. results in considerable expansion and contraction that could cause fractures or wrinkles detrimental to a successful flight. By making allowances for this possibility, many problems are solved before they occur.

3. Determine the temperature absorption and reflection of various colors of coating and materials for metals.

   The environment inside a spacecraft is partially determined by the amount of heat absorbed or radiated. Knowing the principles involved could prove valuable in nonspace applications.
4. Determine the strength of solder alloyed in the different percentages permitted by NASA.

   A very small change in alloy percentages causes considerable variation in solder strength especially at the solidification temperature. Using both NASA alloys (60–40 and 63–37), determine the relative strength of each.
5. Determine what surface preparation and what primer would be most effective for preventing corrosion of ferrous materials in a salt air atmosphere.

   The location of Cape Kennedy and the resulting salt air atmosphere cause much corrosion. Many remedies have been instituted, and their relative efficiencies could be determined experimentally.
6. Determine the "weldability" of two machined surfaces when they mate in space.

   When two machined surfaces mate in the vacuum of space, difficulty in separation results. Determine experimentally just how much the degree of surface finish contributes to this problem.

SAMPLE JUNIOR ENGINEERING PROBLEM OUTLINE

1. *The Problem*
   How to get telemetry information on conditions, functions, and performance of a spacecraft and astronauts.
2. *The Purpose*
   The necessity of getting information from the spacecraft in order to compare with predicted conditions, functions, and performance.
3. *The Need*
   Using this comparative information to make adjustments and decisions regarding the spacecraft.
4. *Hypothesis*
   There must be methods and devices that are possible to use in order to get this information to the persons responsible for all phases of a particular space mission.
5. *Assumption of Outcome*
   If the responsible people are able to get all of the necessary information, then they will be able to make the correct adjustments and decisions for a safe space mission.
6. *Procedures for Testing Hypothesis*
   a. In driving an automobile, how do you know if the engine is performing properly?
   b. How do you get this information?
   c. How does an airplane pilot know if his engine is functioning properly?
   d. How does an airplane pilot know where he is?

e. How does the tower operator know the location, altitude, direction, and identification of an airplane flying near the airport?
f. How do the problems of getting information from the spacecraft differ from the problems inherent in an automobile or aircraft?

7. *Findings and Conclusions*
   a. As space travel becomes more practical, better means of communicating will have to be developed.
   b. As manned space stations are developed, there will be less need for long-range telemetry control equipment.
   c. Magnetic fields of force will continue to play an important part in the development of space travel vehicles.
8. *Recommendations for Further Study*
   a. How will men on the moon power and operate their stations for communicating with earth?
   b. What would be the essential components and functioning of a manned space stage?
9. *References*
   a. Suggested references
      (1) "Instruments and Systems (Aircraft)," Sanderson Films, Inc., Wichita, Kansas—Filmstrip.
      (2) Instrument panel of an automobile
      (3) Stilz, Harry. *Aerospace Telemetry*
      (4) NASA Tech Briefs
         (a) 63–10443
         (b) 63–10567
         (c) 64–10258
         (d) 65–10010
         (e) 65–10195
         (f) NASA SP–5036
      (5) Student references

D. MASS PRODUCTION

The elements of industry were described earlier (See Section 1, Unit 2), and they can be profitably employed in the industrial arts laboratory. Models of spacecraft can be mass-produced in the class giving each student the opportunity to participate in either the planning or the manufacturing. The plans, material sheets, and procedures for such a model are shown here. Several others are described and illustrated in the booklet *Model Spacecraft Construction,* which is available from the U.S. Government Printing Office, Washington, D.C. ($1.00)

Mass Production of Models of the Apollo Command Module

1. *Background*
   In an effort to familiarize and stimulate student interest in space technology, it is suggested that they construct models of the Apollo command module. This experience should stimulate

thinking and experimentation with new materials and processes within the usual activities followed in industrial arts woodworking. Students should develop a feeling for accuracy in following the directions as well as a facility for reading working drawings. Some problem solving techniques should be developed as they study the scientific principles applied to the project. While following this unit, in addition to the development of a knowledge of space technology, students should also be attaining the objectives of contemporary industrial arts. Such objectives as familiarization with industrial concepts (in this case, space industry), safe operation of tools and equipment, consumer knowledge (knowledge of the products of the space program), and occupational information (space occupations) should be a natural outcome of the unit.

2. *Motivation*

Uppermost in the minds of all people involved in the space industry and in the minds of the American public is the Apollo program, which is designed to place a man on the moon in this decade. Many of the current space probes are aimed at checking out the various stages of this program and at getting as much information as possible before the three astronauts are blasted off the launch pad at Cape Kennedy—destination moon. Most of the information presented in the Plastics and Ceramics units of this curriculum document has been geared to the Apollo program. Since this is the only vehicle to return to the earth after the moon trip, and since it is the vehicle in which the astronauts will travel, it is thought fitting to build this teaching unit around this same module. Much of the technology being developed for this moon shot has had the command module as its center. Americans have traditionally valued human life above material gains. This is essential in the space program as well. The design and construction of the command module is the ultimate reflection of this concept. Making models of this module should provide a natural framework to integrate industrial arts with science, social studies, and other school areas. Reports on progress, discussions on fundamental issues, and lessons and assignments should prepare the way for the construction activities. A visit of the Spacemobile might be arranged as a motivational project as well as an extremely important adjunct to the general educational program of the school. A field trip to a space facility can serve as a culminating activity.

3. *Unit Organization*
   a. If the motivation has been adequate, students will want to construct a spacecraft model.
   b. Review such information as the design of the module; interpret the drawings; make lists of materials needed; equipment needs should be noted; connect the tool manipulation with previously learned processes.
   c. Additional information can be gained from consulting the items in the reference sections furnished with these units; by

reading current newspapers and magazines; by consulting contemporary industrial arts textbooks; by utilizing resource people, such as the science teacher, available space technicians, military recruiting personnel, and space technology contractors.

d. The problem will be to construct a model of the Apollo command module following drawings and specifications found in reference 8B2, *Model Spacecraft Construction.*

e. Students should list tools and equipment needed to carry out the project.

4. *Activities*

a. Product development

(1) Interpretation of the drawings of the model. Fig.'s 1–4, 1–5, and 1–6.

(2) Development of the pattern for the outer skin. Fig. 1–7.

(3) Analyze the bill of material. Fig. 1–8.

(4) Analyze the steps for the construction procedure. Fig. 1–9.

(5) Process of construction

(a) Cut out the stock for the heat shield and the nose cone.

(b) Form shape on lathe.

(c) Sand surfaces.

(d) Layout and cut patterns from sheet metal.

(e) Form the shape.

(f) Drill holes for attaching.

(g) Attach outer skin to nose cone and heat shield.

(h) Finish the model.

b. Set up procedures for mass manufacturing the module.

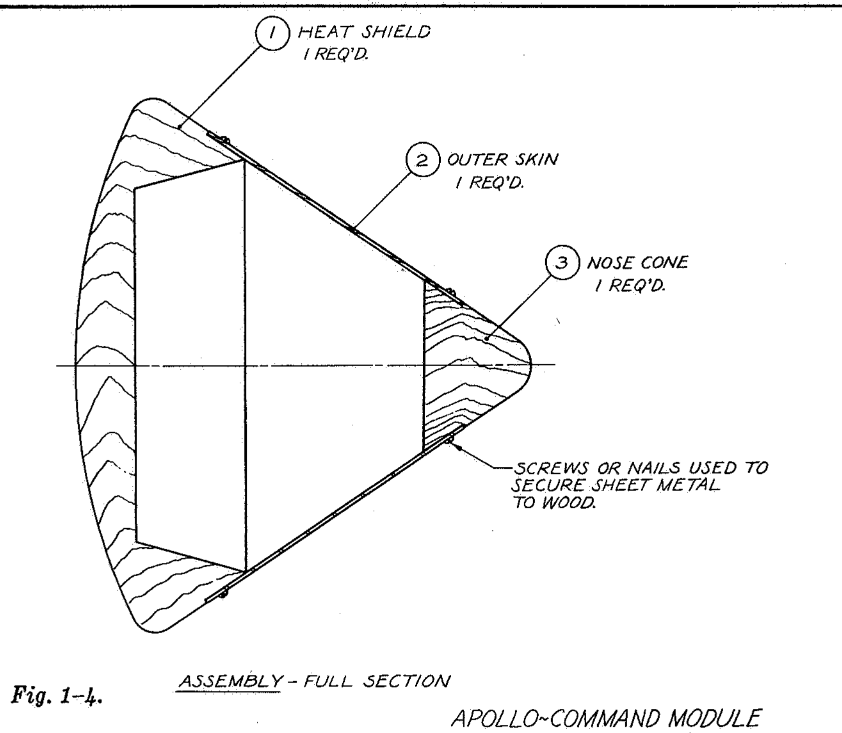
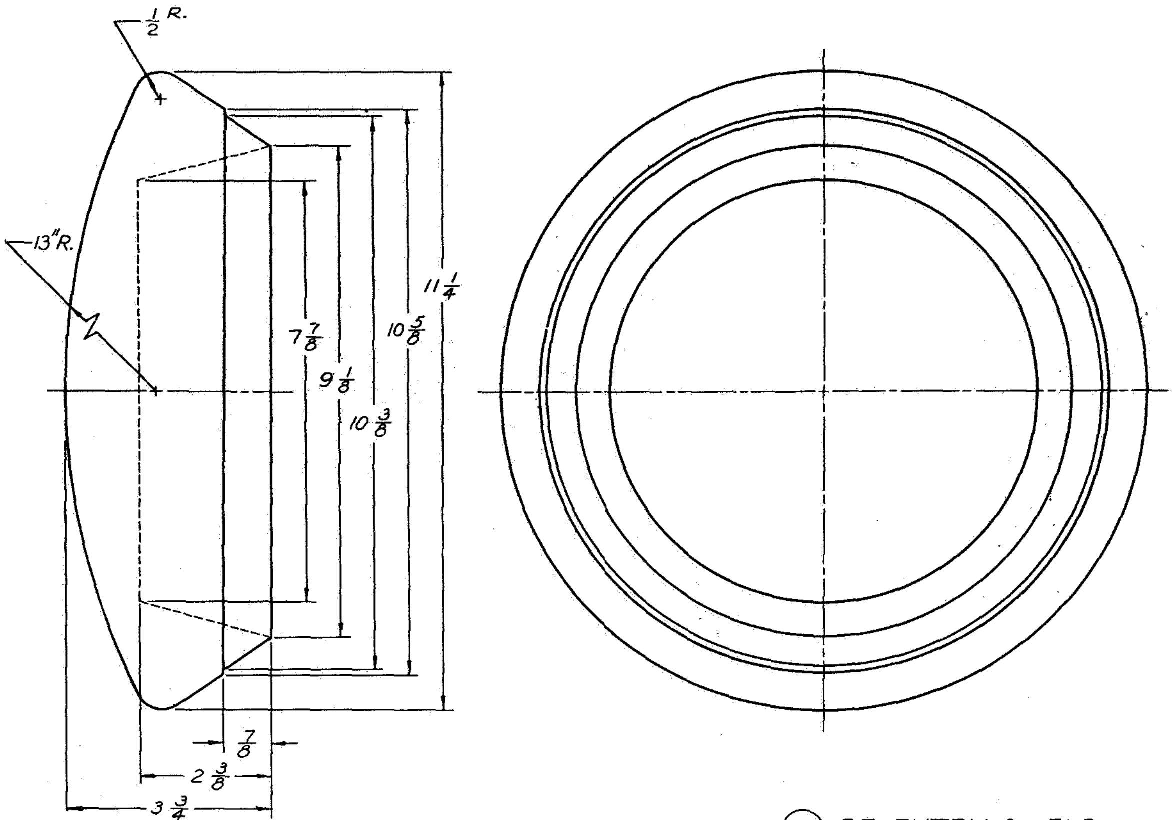
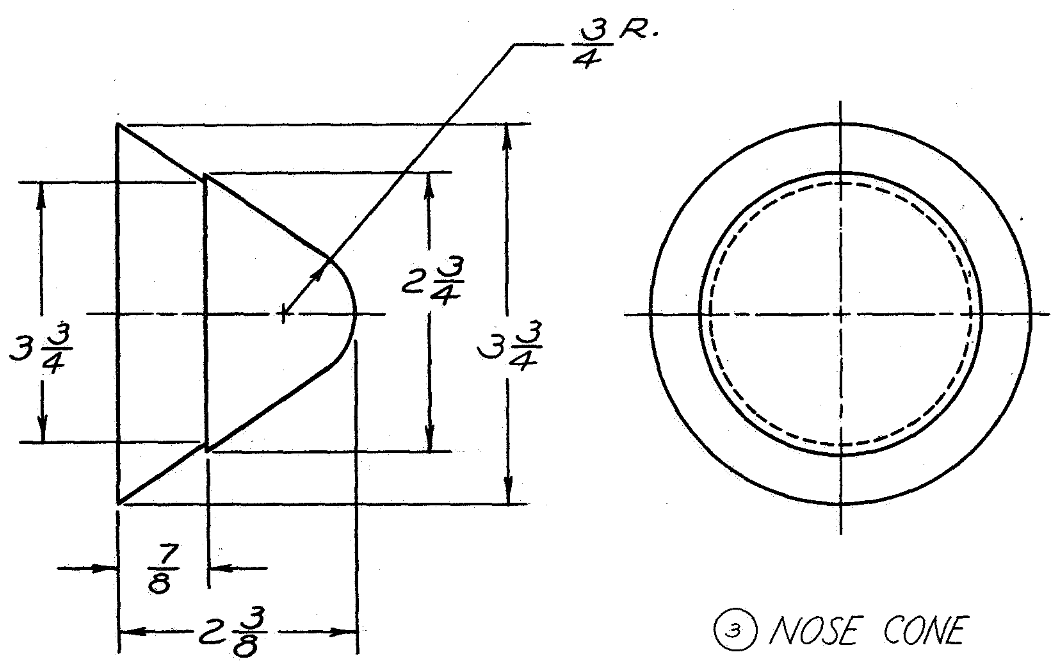


Fig. 1–4.



1/2 R.
13" R.
7 7/8
9 1/8
10 3/8
10 5/8
11 1/4
7/8
2 3/8
3 3/4
① RE-ENTRY SHIELD

Fig. 1–5.



3/4 R.
3 3/4
2 3/4
3 3/4
7/8
2 3/8
③ NOSE CONE

Fig. 1–6.

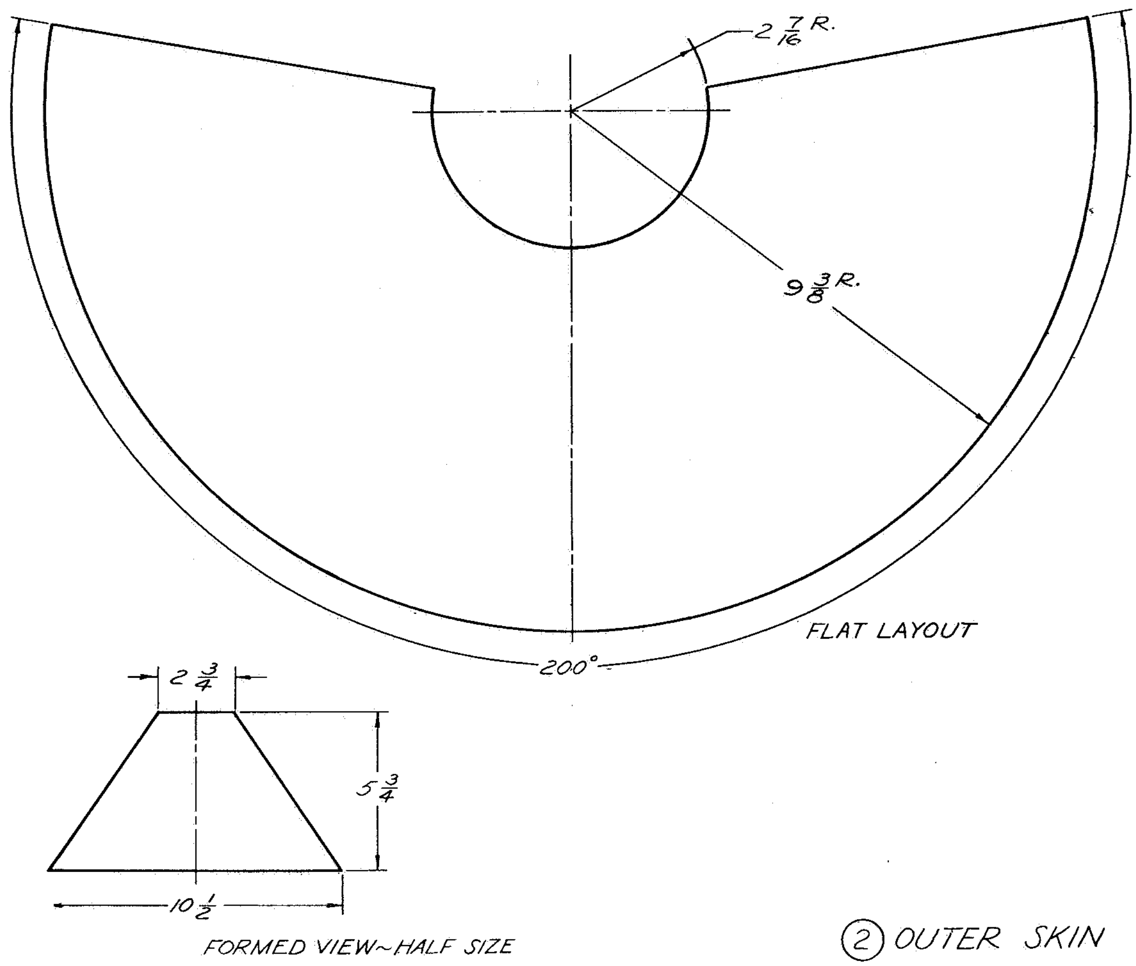


Fig. 1–7.

RECOMMENDED MATERIALS FOR CONSTRUCTION APOLLO

PART NUMBER	NUMBER REQUIRED	RECOMMENDED MATERIAL	COLOR
1	One	Wood or aluminum	White
2	One	Metal—sheet aluminum or cold rolled steel	White
3	One	Wood or aluminum	White

Fig. 1–8.

RECOMMENDED PROCEDURE FOR CONSTRUCTION APOLLO				
PART NO.	SUGGESTED MATERIALS	FABRICATION TECHNIQUE	SURFACE TREATMENT	ASSEMBLY RECOMMEN-DATIONS
1	Wood or cast aluminum	Turn on lathe to specified dimensions	Finish sand or polish surface	
2	Metal—sheet aluminum or sheet steel	Layout and fabricate to specified dimensions		
3	Wood or cast aluminum	Turn on lathe to specified dimensions	Finish sand or polish surface Paint white	Assemble parts no. 1, 2 and 3

Fig. 1–9.

5. *Evaluation*
   a. Accomplishments
      (1) Was student interest maintained throughout the construction of the model?
      (2) Was there evidence of experimentation with new materials and processes?
      (3) Was there evidence of accuracy and craftsmanship throughout the construction?
      (4) Did students follow the specifications of the drawings?
      (5) Did students follow the plan of procedure?
      (6) Was there evidence that students understood the scientific principles involved in the processes carried out?
      (7) Did students practice safety precautions?
      (8) Did students learn the related information about tools, machines, materials, and occupations covered in the unit?
      (9) Was there evidence of the understanding of the importance of space technology in our society?
   b. Success
      (1) Were most of the students able to construct the model with a reasonable degree of success?
      (2) Were the results of the achievement tests satisfactory?
      (3) Is there evidence of student interest to continue studying space technology information and model construction?
   c. Unit improvements
      (1) Re-examine the objectives, motivation, organization, and activities in order to incorporate new ideas, techniques, and procedures which will make the success of the unit more effective.
      (2) Visit and read about space centers, space industries, and space establishments to increase your knowledge and understanding of space technology.

section 4

section 4 appendix I
EDUCATIONAL SERVICES

THE NASA EDUCATION PROGRAMS DIVISION

In "The National Aeronautics and Space Act of 1958," one of the objectives is clearly stated; namely, "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." It is from this phrase and the discussion in the Congress leading to its inclusion in the Act and its amendments that "the Educational Programs Division" gets it charter. The Division is continually reacting to numerous requests for information and aid from students, teachers, and the public in general.

Specifically, NASA Educational Programs Division has been assigned the mission of "assisting in the role of preserving the leadership of the United States in aeronautical and space science and technology by contributing to the development of an informed citizenry and satisfying the needs of the education community." The Division has and will continue to assist schools, colleges, and other educational organizations in gaining a wider knowledge and understanding of the work done by the NASA and the results emanating from the Nation's space program.

The Educational Programs Division at NASA Headquarters in Washington, D.C., is part of the Office of Public Affairs. Here the policy is set and programs and projects are approved and guided. The operational aspects of the program are decentralized to our various centers across the country.

The following are the names and addresses of the Educational Programs Offices in the field and the states they serve:

Educational Services Officer Public Affairs Office NASA Ames Research Center Moffett Field, California 94035	Alaska, Idaho, Montana, Northern California, Oregon, Washington, Wyoming
Educational Programs Officer NASA Electronics Research Center 575 Technology Square Cambridge, Massachusetts 02139	Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont

Educational Programs Officer Public Affairs Office—207.1 NASA Goddard Space Flight Center Greenbelt, Maryland 20771	Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, West Virginia
Educational Programs Office NASA John Kennedy Space Center Kennedy Space Center, Florida 32899	Florida, Georgia, Puerto Rico, Virgin Islands
Educational Programs and Services NASA Langley Research Center Langley Station Hampton, Virginia 23365	Kentucky, North Carolina, South Carolina, Virginia
Educational Services NASA Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135	Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin
Educational Liaison Branch Public Affairs Office NASA Marshall Space Flight Center Huntsville, Alabama 35812	Alabama, Arkansas, Louisiana, Mississippi, Missouri, Tennessee
Educational Programs and Services Branch Public Affairs Office (AP-4) NASA Manned Spacecraft Center Houston, Texas 77058	Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas
Educational Programs NASA Pasadena Office 4800 Oak Grove Drive Pasadena, California 91103	Arizona, Hawaii, Nevada, Southern California, Utah

Industrial arts teachers wanting services should contact the field officer of the Center which serves his state.

The Division has divided its efforts into five basic programs:

1. Professional Education Conferences
2. Teacher Education Services
3. Development of Instructional Resources
4. Lecture-Demonstration Programs
5. Miscellaneous Educational Activities

The first of these, "Professional Education Conferences," includes meeting with educational groups, such as state and national industrial arts teacher groups.

The second program, "Teacher Education Services," has primarily operated through summer workshops, seminars, and institutes. NASA has attempted to increase understanding of the developments in space science and technology on the part of both pre and in-service teachers. Basic physical principles and samples of tools and techniques are pre-

sented so that each teacher takes away with him a useful experience, one that can be used in the classroom. NASA varies its participation depending on the sponsoring institution from providing reading or audio-visual materials to full assistance in organizing and conducting the activity.

The third program of "Development of Instructional Resources" includes not only the in-house development of educational publications, television and radio programs, films, and film strips but also the initiating and/or encouragement of such resources as curriculum guides and bulletins, course syllabi, series of work units, etc. NASA is going ahead with single concept films, pamphlets with teacher guides, ETV programs for elementary grades, and a whole series of specific materials that they hope will enhance the learning process. NASA does not visualize a need for new courses as such. NASA feels that the education process can be enhanced and enriched by the addition of space facts and materials in appropriate places. These facts and materials stimulate and motivate students and will serve to contribute to the general goals of excellence in both teaching and learning. NASA wants to help the educational community meet the needs of the space age through dissemination of the knowledge and information flowing from the Space Program.

The fourth program is the "Lecture-Demonstration Program." This is the so-called Spacemobile—panel trucks loaded with models, visual displays, experiments, films, slides, etc., and manned by trained teachers. The unit can back up to a school auditorium and unload and set up in about 30 minutes to present 45–55-minute lecture-demonstration on space programs and concepts. The lecturers can visit appropriate shops and laboratories for in-depth discussions and with proper planning can spend an entire day in the school.

The fifth program titled "Other Educational Programs" includes guidance and counseling, science fairs, adult education, work with Boy Scouts, and a number of other programs adjunct to the teacher.

Although there is a need created by space research and development for more technically trained manpower, this is not the whole story. There is a need for a knowledgeable citizenry, one that understands the powerful societal force exerted by this new industrial complex. It is so important that the student who will not become a scientist, an engineer, or a technician will be made aware of the implications of this new technology. It becomes the industrial arts teachers role to interpret, relate and systematize the facts that students like to collect. This is a difficult role. NASA, through its Educational Programs Division in Washington, D.C., and its offices in the field, will do all it can to aid.

section 4 appendix II
NASA MOTION PICTURES

WHO MAY BORROW FILMS

Educational, civic, industrial, professional, youth activity and Government organizations are invited to borrow films from the NASA Regional Film Library which serves their area. There is no film rental charge, but the borrower pays return postage (Fourth Class Rate) and insurance costs. Films are loaned for group showings only and are not available for showings by individuals in homes. Since custody involves both legal and financial responsibility, films cannot be loaned to minors.

To expedite shipment, the requester should give the name and address, including zip code, of the person and organization assuming responsibility for the film and specify the showing date and an alternate date. It is also advisable to indicate an alternative in case the film requested is not available.

Please address requests to the appropriate NASA Regional Film Library according to the destination of the film.

If you live in:	Write to:
Alaska, Idaho, Montana, Northern California (North of Los Angeles Metropolitan area), Oregon, Washington, Wyoming	NASA Ames Research Center Public Affairs Office Moffett Field, California 94035
Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont	NASA Electronics Research Center Educational Programs Office 575 Technology Square Cambridge, Massachusetts 02139
Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, West Virginia,	NASA Goddard Space Flight Center Photographic Branch, Code 253 Greenbelt, Maryland 20771
Florida, Georgia, Puerto Rico, Virgin Islands	NASA John F. Kennedy Space Center Code SOP 323 Kennedy Space Center, Florida 32899

Kentucky, North Carolina, South Carolina, Virginia	NASA Langley Research Center Langley Station Public Affairs Office Mail Stop 154 Hampton, Virginia 23365
Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin	NASA Lewis Research Center Office of Educational Services (4-4) 21040 Brookpark Road Cleveland, Ohio 44135
Alabama, Arkansas, Louisiana, Mississippi, Missouri, Tennessee	NASA George C. Marshall Space Flight Center Public Affairs Office Huntsville, Alabama 35812
Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas	NASA Manned Spacecraft Center Public Affairs Office (AP-2) Houston, Texas 77058
Arizona, Hawaii, Nevada, Southern California (San Luis Obispo, Kings, Tulare and Inyo Counties)	NASA Pasadena Office 4800 Oak Grove Drive Pasadena, California 91103

Television stations may order films, unless otherwise noted, for unsponsored public service or sustaining telecasts.

Since these films are U.S. Government property, reproduction or editing of them for any purpose is prohibited unless specific written authority is granted by the Public Affairs Office where film loan request is made.

Films listed below are 16mm, sound productions in color or black and white, as indicated. Each film is designated by a code letter as suitable for: (U) Upper Elementary Grades 4–6; (S) Secondary Grades 7–12; (A) Adult and College Level.

GENERAL INTEREST FILMS

ALOUETTE—CANADA'S FIRST SATELLITE. HQa 94—1963—B/W, 14 min. Shows the design and operation of a satellite whose mission is to investigate the ionosphere. (Not cleared for commercial TV.) (S–A)

AMERICA IN SPACE. HQ 103—1963—Color, 14 min. Brief overview of NASA's first five years showing the growth of America's space program from Explorer I through early years of Project Apollo and manned exploration of the moon. (S–A)

ARIEL—THE FIRST INTERNATIONAL SATELLITE. HQ 58—1963—Color, 13 min. Describes the sun's effects on earth's ionosphere and how this in turn affects radio transmission. The importance of international cooperation in space investigation is stressed when this British-built satellite was launched and tracked by the United States. (S–A)

ARIEL II. HQa 115—1963—Color, 26½ min. The second international satellite and how it was developed and placed into orbit to gain new knowledge about the structure of the universe. Shows research and development, assembly, testing, evaluation and launching.

BEFORE SATURN. HQa 76—1962—Color, 14½ min. The history of rockets from early Chinese use up to and including the giant Saturn I launch vehicle. (S–A)

THE BIG CHALLENGE. 1967—color, 28 min. The construction story of the John F. Kennedy Space Center, NASA and complex 39, the launch complex for this nation's manned lunar landing. Emphasis is given the vehicle assembly building, the skilled tradesmen, technicians, craftmen, engineers, and the equipment necessary for this nation's manned journey to the moon. (S–A)

THE BIOSATELLITE PROGRAM—BETWEEN THE ATOM AND THE STAR. HQ 107—1965—Color, 28 min. Depicts the need for biological experiments in a zero gravity environment; how the biosatellite makes its occupants weightless; types of experiments planned; and how the experiments will contribute to knowledge of basic life processes and toward man's living in space. (S–A)

CELESTIAL MECHANICS AND THE LUNAR PROBE. HQa 26—1958—Color, 9½ min. Describes mechanics of guiding lunar probes. (S–A)

THE CLOUDS OF VENUS. HQa 82—1963—Color, 30 min. The planning, launching and results of the Mariner II voyage past Venus (S–A)

ECHO IN SPACE. HQ 37—1961—Color, 14 min. The story of Thor-Delta II which placed Echo I, a 100-foot sphere in orbit as a passive communications satellite. (S–A)

ELECTRIC PROPULSION. HQ 96—1965—Color, 24 min. Shows in nontechnical terms, what electric propulsion is, how it works, why it is needed, its present status and program for development, and how it may be used for both manned and unmanned missions. (S–A)

FATHER OF THE SPACE AGE. HQa 54—1961—B/W, 18½ min. Traces the development of Dr. Robert Goddard's "moon rocket" research from his early manhood through his final efforts in development of liquid fueled guided rockets. Includes commentaries by Mrs. Goddard, original motion picture coverage of Dr. Goddard's rocket tests, scenes of the dedication of Goddard Space Flight Center, and the posthumous presentation of the Langley Medal award in 1959. (Not cleared for commercial TV.) (S–A)

THE FLIGHT OF FAITH 7. HQa 101—1963—Color, 28½ min. Astronaut Gordon Cooper's flight on August 15–16, 1963, is documented from preflight training and medical checkouts to launch, flight, and recovery. (S–A)

THE FOUR DAYS OF GEMINI 4. HQa 134—1965—Color, 27½

min. Covers the Gemini-Titan 4 mission of Astronauts James McDivitt and Edward White. Includes prelaunch and launch activities, Astronaut White's spectacular "space walk" and many other experiments conducted during the mission including photographs of the earth. Sound track uses narration and actual voice communications of the Astronauts inside the spacecraft. Shows details of White's space suit and "space gun." (U–S–A)

FREEDOM 7. HQa 51—1961—Color, 28½ min. Pictures Astronaut Shepard's suborbital launch. Describes part of his training, his activities during the last few days before launch, his recovery and reception aboard the rescuing aircraft carrier. (S–A)

FRIENDSHIP 7. HQa 59—1962—Color, 58 min. Depicts the day Astronaut John Glenn made the first American orbital space flight. Documents Project Mercury including a close look at tracking stations around the world. (S–A)

THE HARD ONES. HQ 120—1965—Color, 15 min. Describes the difficulties and problems encountered in designing, building, and operating unmanned satellites for scientific research and practical applications such as communications and weather forecasting. Features the Orbiting Geophysical Observatory designed to gather knowledge about the earth, sun, and their inter-relationships. (S–A)

INTERNATIONAL COOPERATION IN SPACE. HQ 60—1965—Color, 23 min. Describes NASA's program of cooperation with many countries in launching international satellites, inclusion of foreign experiments, sounding rocket research, global tracking networks. (S–A)

THE JOHN GLENN STORY. HQa 90—1963—Color, 30 min. A biography of Astronaut John Glenn narrated by Jack Webb. Stresses American ideals as exemplified in the life of Astronaut Glenn; the importance of physical, mental and moral values. Follows his youthful days in New Concord, Ohio, his heroism as a combat pilot in World War II and the Korean War, and his momentous adventure as the first American to orbit the earth. (U–S–A)

LIVING IN SPACE.—1965—

Part I, HQ 131–A. "A Case for Regeneration, Color, 12 min.
Part II, HQ 131–B. "Regenerative Processes," Color, 20 min.
Part III, HQ 131–C. "A Technology for Spacecraft Design," Color, 12 min.

A series of three films which depict various problems which man must face and master as he makes extended journeys in space. Part I illustrates the requirements for oxygen, water, food, and waste disposal which must be incorporated in a regenerative or recycling system. Part II presents a more comprehensive view of the physics, chemistry and mechanics involved in a life support system, and the possible solutions to physical problems such as bathing, shaving, eating and sleeping in a weightless environment. Part III shows the technology being developed for a regenerative system for long duration manned space flights. Parts I and III, (S–A); Part II, (U–S–A)

LOG OF MARINER IV. HQa 159—1966—Color, 27 min. Documentary illustrating the planning, development, launching and data returned by the Mariner IV spacecraft which photographed the surface of Mars. The film describes the major problems of trajectory, mid-course maneuver, and translation of digital information into photographs; and includes the photographs of the Martian surface. (S–A)

THE MASTERY OF SPACE. HQ 9—1962—Color, 58 min. Traces the development of Project Mercury and documents the sub-orbital flight of Freedom 7 as well as the orbital flight of Friendship 7 on February 20, 1962. Projects Gemini, Apollo and the Saturn booster are also briefly discussed. (S–A)

MEN ENCOUNTER MARS. HQ 149—1965—B/W, 28½ min. Documentary about the engineers and scientists who planned and directed the complex mission of Mariner IV to photograph the Martian surface. (S–A)

A MOMENT IN HISTORY. HQa 122—1964—Color, 13½ min. Shows the events leading to the presentation of honorary U.S. citizenship to Winston Churchill by President Kennedy on April 6, 1963. The live television transmission was sent via relay satellite from the White House to England.

ORBITING SOLAR OBSERVATORY. HQa—1962—Color, 26 min. Describes the Orbiting Solar Observatory spacecraft which is designed to gather information concerning the sun's effect on the earth. (S–A)

PROJECT APOLLO—MANNED FLIGHT TO THE MOON. HQ 88—1963—Color, 13 min. Major steps in the project to place men on the moon and get them back to earth safely. Shows principal features of the Gemini spacecraft, the Titan booster and the kinds of operations to be carried out under the Gemini program. Covers the complete sequence of events for the manned lunar landing from earth launch to return.

PROJECT ECHO. HQ 24—1960—Color, 27 min. Tells the story of launch vehicles Thor-Delta I and Thor-Delta II. Thor-Delta II placed Echo I, a 100-foot sphere in orbit as a passive communications satellite in August, 1960. (S–A)

RANGER VII PHOTOGRAPHS OF THE MOON. HQa 118—1964—B/W, 7 min. TV photographs of the moon, taken by Ranger VII as it approached the moon on July 31, 1964, are shown. (S–A)

RANGER VIII TELEVISION PICTURES OF THE MOON. HQa 132—1965—B/W, 7½ min.

RANGER IX TELEVISION PICTURES OF THE MOON. HQa 133—1965—B/W, 6½ min.

Short films of lunar photographs taken by the Ranger spacecraft in February and March, 1965, with a narrative account of the missions. The photographs have been printed to provide continuous views as the spacecraft descends toward the moon until the moment of impact, and

wide and narrow angles are included. (U–S–A)

RETURNS FROM SPACE. HQa 156—1966—Color, 27 min. Some of the varied "spin-off" benefits and products of space research and development are demonstrated. These include use of sensors for monitoring hospital patients, devices which aid the disabled, the uses of freeze-dried foods by campers, new technological tools and materials, and microminiaturization of electronic components. (U–S–A)

SATURN LAUNCH COMPLEX 34. HQa 70—1962—Color, 16½ min. Dr. Kurt Debus, Director, NASA J. F. Kennedy Space Center, discusses with the help of models and diagrams, the complexities of the building and operation of Saturn Launch Complex 34. Dr. Debus also tells why a newer and larger complex than #34 was needed to launch the Saturn V vehicles which will carry man to the moon. (S–A)

RESEARCH PROJECT X–15. HQ 79—1966—Color, 27 min. The story of the development of the X–15 research airplane as the latest in a series of experimental aircraft, and the results obtained from X–15 flights. Dramatic photography of the X–15 flights at the edge of space and landings on dry lake beds included. (S–A)

SATURN PROPULSION SYSTEMS. HQa 77—1962—Color, 14 min. The theory of reaction engines and the application of the theory in the Saturn propulsion system. (S–A)

THE SHAPE OF THINGS TO COME. HQ 106—1965—Color, 21 min. Describes the need for advanced research and provides examples of promising research programs. (A)

STEPS TO SATURN. HQa 67—1962—Color, 22 min. Depicts the background and development processes of the Saturn program. The film shows the flight of the first Saturn vehicle. (S–A)

TIROS, EXPERIMENTAL WEATHER SATELLITE. HQa 25—1960—Color, 14 min. Depicts the preparation and launch of the weather satellite Tiros I, April 1, 1960. Tiros and future meteorological satellites are described. (S–A)

TIROS II, EXPERIMENTAL WEATHER SATELLITE. HQa 31—1961—Color, 6 min. Shows launch of Tiros II, November 23, 1960, and summarizes results of the 3 months of activity during which Tiros I transmitted TV pictures of the earth's cloud cover. Cloud cover pictures from Tiros I are shown, as well as the volume of taped data. Film describes the TV cameras used to photograph the earth's cloud cover and subsystems used to measure earth and atmospheric radiation. (A)

TRIAL BALANCE. HQ 123—1965—Color, 27 min. Presents current knowledge in space science, particularly that gained through analyses of information acquired from spacecraft. (S–A)

UNIVERSE. HQa 91—1960—B/W, 28 min. Explores by animation and special effects the solar system, Moon, Mars, Venus, Mercury, Earth, Saturn and on into the galaxies beyond the Milky Way. (Not

cleared for television.) (U–S–A)

A VOICE FOR MERCURY. HQa 66—1961—Color, 14½ min. Describes the construction and equipping of NASA's worldwide Mercury Tracking network. (S–A)

THE WORLD BEYOND ZERO. HQa 121—1961—Color, 28 min. The story of a satellite and the cooperative efforts of the world-wide network tracking stations linking the space scientists and engineers with their orbiting spacecraft. Film views Cape Kennedy; Lima, Peru; Santiago, Chile; Johannesburg, South Africa; Anchorage, Alaska; Winkfield, England; and Woomera, Australia. The film stresses cooperation between nations engaged in the exploration of space. (U–S–A)

TELEVISION FILMS

The following films were originally produced on videotape as a television series and are now available on 16mm black and white film with sound. Each film contains both the series and individual program title. Requesters may order by individual film or by series.

SPACE: MAN'S GREAT ADVENTURE

THE DREAM THAT WOULDN'T DOWN. HQk 125—1965—26:48 min. The dream of Dr. Robert Goddard, the father of rocketry, is explored and examined through reminisences of Mrs. Goddard. Included is historic footage of Dr. Goddard's early experiments and the personal commentary of Mrs. Goddard. (U–S–A)

A IS FOR AERONAUTICS. HQk 129—1965—26:34 min. The first "A" in NASA concerns aeronautical research, and this program traces the American contribution to flight . . . from the Wright Brothers through supersonic transport. The viewer meets some of the men who have made modern flight possible, and sees the inner workings of a major flight research facility. (S–A)

SCIENCE REPORTER

THE FIRST SOFT STEP. HQk–SR1—1966—28:38 min. A detailed look at the overall mission and accomplishments of the Surveyor program to soft-land a picture-taking craft on the surface of the moon. The program introduces the viewer to the spacecraft and to top scientists involved in its flight. In concludes with actual photos sent back to earth from Surveyor One. (S–A)

LANDING ON THE MOON. HQk–SR2—1966—28:17 min. The Lunar Module referred to by some as the "moon bug," is the topic of this film. The viewer is taken inside the module and is given a simulated ride to the surface of the moon. (S–A)

FOOD FOR SPACE TRAVELERS. HQk–SR3—1966—28:31 min. A report on the progress and problems involved in developing, preparing and eating nutritious and tasteful foods during extended space journeys. Host John Fitch visits a space foods kitchen and samples foods prepared for astronauts. (S–A)

POWER FOR THE MOONSHIP. HQk–SR4—1966—28:23 min. The fascinating new world of fuel cells is explored in this film. Viewers are shown working models of the fuel cell plants for the Apollo spacecraft, and are given a hint of possible future uses here on earth. (S–A)

SUITED FOR SPACE. HQk–SR5—1966—28:30 min. The history of space suits, from Mercury through Apollo to future concepts is shown. Also included is a close-up look at the Portable Life Support System an astronaut will wear on the surface of the moon. (S–A)

COMPUTER FOR APOLLO. HQk–SR6—1966—29:03 min. Guidance and navigation on man's first trip to the moon will depend a great deal on the Apollo Guidance Computer. The film provides a look at this fascinating computer—how it works, how it is assembled. (S–A)

ROOM AT THE TOP. HQk–SR7—1966—28:13 min. At the top of the giant Saturn-Apollo is the Command Module, the crew quarters, flight center and command post for the flight to the moon. This all-important room at the top of Saturn is examined in detail. (S–A)

SPACE MEDICINE. HQk–SR8—1966—28:31 min. Dr. Charles Berry discusses and shows the medical progress and problems of sending a human being into space and concludes that, so far, there are no serious problems. A fascinating look at the medical program for Manned space flight. (S–A)

RETURNING FROM THE MOON. KQk–SR9—1966—28:21 min. This film explores the problem of getting the Apollo Command Module safely back through the atmosphere to Earth. Explores the problems of guidance and heating and the manufacturing process for the ablative heart shield. (S–A)

TICKET THROUGH THE SOUND BARRIER. HQk–SR10—1966—28:07 min. The Supersonic Transport development program is explored in this film. The viewer is taken on a personal inspection trip of contending configurations and gets to examine each. Also included is a "ride" in a simulated SST. (S–A)

WALLOPS ISLAND LAUNCH FACILITY. KQk–SR11—1966—28:42 min. The world of sounding rockets for scientific experiments is examined in this film as "Science Reporter" host John Fitch visits the NASA launching site on the Virginia coast. The story of a little-known but important part of the space program. (S–A)

GEMINI FLIGHT FILMS

Report films on each Gemini flight (Gemini III through XII) are available upon request. They are all 16 mm, in color, with sound and running times of approximately 10 minutes each.

TECHNICAL FILMS

A list of technical films about NASA projects may be obtained by writing to: NASA Headquarters, Code FAD–2, Washington, D.C. 20546.

TECHNOLOGY UTILIZATION

These films would be of interest to scientists and engineers in Government and industry; high school students; science and engineering teachers; and, senior and graduate, university science and engineering students.

AN ENERGY ABSORPTION PROCESS EMPLOYING FRANGIBLE METAL TUBING. HQa 150—1964—Color, 8 min. Film shows a frangible tube shock absorber relying on the principle of fragmentation. The device provides extremely high energy absorption and was developed for use as a landing impact absorber for spacecraft. (S–A)

HAZARDS OF TIRE HYDROPLANING TO AIRCRAFT OPERATION. HQa 112—1963—Color, 15 min. This film explains the phenomena of tire hydroplaning, under what conditions it occurs, and the resulting hazards to aircraft operations. Based upon tire studies at NASA's Langley Research Center, the film was produced to identify and draw particular attention to the wet runway hazard. The film can be used best as a training film for flight and flight safety personnel. (S–A)
(This is a film supplement to a NASA publication: PHENOMENA OF PNEUMATIC TIRE HYDROPLANING. November 1963—NASA Publication—TN–D–2056./)

REDUCED GRAVITY SIMULATOR FOR STUDY OF MAN'S SELF LOCOMOTION. HQa 124—1964—Color, 10 min. Shows an arrangement of cables and harnesses on an overhead track, which very simply duplicates the effects of reduced gravity such as occurs on the moon. The unit has been used in training astronauts to acquaint them with this low gravity effect. (S–A)

**For information on publications related to NASA Technical Films contact Office of Scientific and Technical Information, NASA Hq., Code USS, Washington, D.C. 20546.*

section 4 appendix III

Conference Program and Participants

A SPACE TECHNOLOGY CONFERENCE FOR INDUSTRIAL ARTS EDUCATORS

Indian Harbour Pines Motor Lodge
Indian Harbour Beach, Florida

May 3–6, 1966

Sponsored By
CENTER FOR CONTINUING EDUCATION
UNIVERSITY OF SOUTH FLORIDA
Tampa, Florida

In Cooperation With
STATE DEPARTMENT OF EDUCATION
Tallahassee, Florida

and

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHN F. KENNEDY SPACE CENTER
Florida

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Industrial Education Department
Western Michigan University
Kalamazoo, Michigan

Dr. Thomas Brenna, Coordinator
Industrial Education
West Virginia University
Morgantown, West Virginia

Dr. Ira H. Johnson, Professor
Industrial Arts Department
Mankato State College
Mankato, Minnesota

Mr. Warren Smith, Coordinator
Technical Sciences
Nova High School
Fort Lauderdale, Florida

Dr. George Ditlow, Professor
Industrial Arts Department
Millersville State College
Millersville, Pennsylvania

Dr. John R. Lindbeck, Professor
Industrial Education Department
Western Michigan University
Kalamazoo, Michigan

CONFERENCE PLANNING COMMITTEE

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Cambridge, Massachusetts

Dr. Ralph V. Steeb, Consultant
Industrial Arts Education
State Department of Education
Tallahassee, Florida

Mr. Robert S. Tiemann
Educational Programs Division, NASA
Washington, D.C.

TUESDAY, MAY 3, 1966

4:00 p.m.– 6:00 p.m.	Registration—Indian Harbour Pines Motor Lodge
6:30 p.m.	Banquet Hall

Presiding:
Mr. Harold E. Mehrens, Jr.
Education & Community Services Branch
John F. Kennedy Space Center, NASA
Kennedy Space Center, Florida

Welcome:
Mr. Burgess A. Meadows
County Coordinator of Vocational Education & Industrial Arts
Brevard County Board of Public Instruction
Titusville, Florida
Dr. Calvin C. Miller, Director
Center for Continuing Education
University of South Florida
Tampa, Florida
Mr. Paul O. Siebeneichen, Chief
Education & Community Services Branch
John F. Kennedy Space Center, NASA
Kennedy Space Center, Florida

Orientation to Conference Program & Purpose:
Mr. James S. Pope, Program Adviser
Center for Continuing Education
University of South Florida
Tampa, Florida

Overview of the Curriculum Document Project:
Dr. John L. Feirer, Head
Industrial Education Department
Western Michigan University
Kalamazoo, Michigan

WEDNESDAY, MAY 4, 1966

8:15 a.m.	Buses depart for John F. Kennedy Space Center
9:00 a.m.–10:00 a.m.	*Frontiers of Space* Mr. Charles Coleman NASA Lecturer
10:30 a.m.– 1:00 p.m.	Tour of Facilities at Kennedy Space Center and Cape Kennedy Air Force Station
2:00 p.m.– 5:00 p.m.	Tour of Technical & Support Facilities
2:00 p.m.– 2:45 p.m.	Group 1—Maintenance Shop Group 2—Central Instrumentation Facility
2:45 p.m.– 3:30 p.m.	Group 1—Central Instrumentation Facility Group 2—Maintenance Shop
3:30 p.m.– 4:15 p.m.	Group 1—Manned Spacecraft Operations Building—High Bay Group 2—Fluid Test Complex & Pyrotechnic Installation Building
4:15 p.m.– 5:00 p.m.	Group 1—Fluid Test Complex & Pyrotechnic Installation Building Group 2—Manned Spacecraft Operations Building—High Bay
7:00 p.m.	Dinner—Banquet Hall *Announcements:* Dr. John L. Feirer Group Sessions

THURSDAY, MAY 5, 1966

8:30 a.m.–11:45 a.m.	Morning Session *Presiding:* Mr. Raymond Ginn, Consultant Industrial Arts Education State Department of Education Atlanta, Georgia
8:30 a.m.– 9:30 a.m.	*Correlating Space Technology and Information with Industrial Arts Education* Dr. Donald Maley, Chairman Industrial Arts Department University of Maryland College Park, Maryland
9:45 a.m.–10:45 a.m.	*Educational Services of NASA* Mr. Robert S. Tiemann Educational Programs Division NASA Headquarters Washington, D.C.
10:45 a.m.–11:45 a.m.	*Launch Facilities—Design & Construction* Mr. Bradley L. Baker, Chief Spacecraft & Support Facilities Branch John F. Kennedy Space Center, NASA Kennedy Space Center, Florida
1:00 p.m.– 5:15 p.m.	Afternoon Session *Presiding:* Dr. Ralph V. Steeb, Consultant Industrial Arts Education State Department of Education Tallahassee, Florida

1:00 p.m.- 2:00 p.m.	*Certification Standards for High Reliability in Connections* Mr. Norman R. Perry Space Systems Quality Control Representative Quality Division John F. Kennedy Space Center, NASA Kennedy Space Center, Florida
2:15 p.m.-3:00 p.m.	*Photography* Mr. Carl N. Brewster, Supervisor Motion Picture Film Production Technicolor, Inc. Kennedy Space Center, Florida
3:15 p.m.- 4:15 p.m.	*Electronics—Tracking & Telemetry* Mr. Elliott Zimmerman, Asst. Chief Telemetric Systems Division John F. Kennedy Space Center, NASA Kennedy Space Center, Florida
4:15 p.m.- 5:15 p.m.	*Plastics and Ceramics* Mr. W. S. Roden Manager, Avco-Florida Avco Space Systems Division Kennedy Space Center, Florida
7:00 p.m.	Banquet Hall *Presiding:* Mr. Manuel A. Hernandez Director, Industrial Arts Department of Education Hato Rey, Puerto Rico *NASA Technology Utilization Program* Mr. James O. Harrell Patent Counsel & Technology Utilization Officer John F. Kennedy Space Center, NASA Kennedy Space Center, Florida *Announcements:* Dr. John L. Feirer Group Sessions

FRIDAY, MAY 6, 1966

9:00 a.m.-11:30 a.m.	Morning Session—Banquet Hall *Conferees to develop a Plan for Correlating Aerospace Information and Materials with the Industrial Arts Programs* *Presiding:* Dr. John L. Feirer (After the session purpose is announced, the conferees will be divided by content area into 5 groups of 15 for discussion and collection of suggestions for the curriculum document.) Group 1—*Metals* *Presiding:* Dr. Ira H. Johnson, Professor Industrial Arts Department Mankato State College Mankato, Minnesota

Group 2—*Design, Drafting, Experimentation, Photography*

Presiding: Dr. John R. Lindbeck, Professor
Industrial Arts Department
Western Michigan University
Kalamazoo, Michigan

Group 3—*Electronics*

Presiding: Dr. George Ditlow, Professor
Industrial Arts Department
Millersville State College
Millersville, Pennsylvania

Group 4—*Power and Engines*

Presiding: Mr. Warren Smith, Head
Industrial Arts Department
Nova High School
Fort Lauderdale, Florida

Group 5—*Plastics and Ceramics*

Presiding: Dr. Thomas Brennan, Chairman
Industrial Arts Department
West Virginia University
Morgantown, West Virginia

11:30 a.m.–12:00 noon

Project Directors Panel Discussion

Comments

Mr. William P. Danenburg, Coordinator
Center for Continuing Education
University of South Florida
Tampa, Florida

Mr. Harold E. Mehrens, Jr.
Education & Community Services Branch
John F. Kennedy Space Center, NASA
Kennedy Space Center, Florida

LIST OF PARTICIPANTS

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New Smyrna Senior High
New Smyrna Beach, Florida

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South Seminole Junior High
Casselberry, Florida

Mr. Herbert C. Beacham
Florida A & M University
Tallahassee, Florida

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Citrus Grove Junior High
Miami, Florida

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Mr. Glen Fardig
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Atlanta, Georgia

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